INTO THE BLUE:

EXPLORATION OF BUSINESS IDEAS OF THE WOAD PLANT (ISATIS TINCTORIA)

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1 ABSTRACT

Sustainable ecological products and alternatives to conventional products are becoming continuously more important. This work investigates different possibilities to produce and market products from the plant woad. The main focus is on the attitudes, expectations, success factors and obstacles of woad experts who have come into contact with the plant in different ways, from science to plant cultivation and business experience. These were first summarised and categorised on the basis of existing literature and then checked with the help of guideline-supported expert interviews. A lot of results from the literature could be reconfirmed. However, some new findings from the interviews allow conclusions to be drawn about further possibilities, challenges, problems and approaches to solutions.

FIGURE 1: ISATIS TINCTORIA L.

Lindman C.A.M., (1905). Isatis Tinctoria Illustration Platte 213

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2.1 LIST OF ABBREVIATIONS

BASF	Badische Anilin und Sodafabrik
BBA	Biologische Bundesanstalt für Land- und Forstwirtschaft (Federal Biological Institute for Agriculture and Forestry)
DBU	Deutsche Bundesstiftung Umwelt (German Federal Foundation for the Environment)
DZHD	Deutsches Zentrum für Handwerk und Denkmalpflege in Fulda (Centre for Crafts and Monument Conservation)
HKI	Hans-Knoll-Institut für Wirkstoffforschung in Jena (Hans Knöll Institute for Drug Research)
I. tinctoria	Isatis tinctoria
JKI	Julius-Kühn-Institut
LFE	Förderung der Zusammenarbeit in der Land-, Forst-, und Ernährungswirtschaft in Thüringen (Promotion of cooperation in agriculture, forestry and food management in Thuringia)
FNR	Fachagentur für Nachwachsende Rohstoffe (Agency for Renewable Resources)
MDR	Mitteldeutscher Rundfunk (Broadcast of middle Germany)
ÖPM	Ökotrend Projekt und Marketing GmbH
TCM	Traditional Chinese Medicine
TFZ	Technlogie und Förderzentrum (Technology and Promotion Centre)
TLL	Thüringer Landesanstalt für Landwirtschaft (Thuringian State Institute for Agriculture)

TLLLR	Thüringer Landesamt für Landwirtschaft und Ländlichen Raum (Thuringian State Office for Agriculture and Rural Areas)
TWF	Thüringer Waid Forschungs GmbH (Thuringian woad research Ltd.)
TWV	Thüringer Waid Verarbeitungs GmbH (Thuringian woad processing Ltd.

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3 INTRODUCTION

3.1 PRE-THEORETIC OVERVIEW

This study seeks to show why the ancient plant of dyer's woad is interesting for business ideas - a plant that brought wealth to various areas in Europe like England, France, Italy and Germany during medieval times, because of the extraction of blue dyes.

The economic importance of woad gradually diminished when natural indigo was imported from Asia from the 16th century. The new raw material had approximately 30-times higher dye precursor content and was therefore more lucrative than woad. From this point on, the woad business went downhill and the plant increasingly fell into oblivion. The 30-year war also triggered a major setback for the woad economy of the city of Erfurt. Towards the end of the 19th century the chemical industry started developing the indigo synthesis. Adolf v. Baeyer established the fully synthetic production of Indigo from Isatin. Starting in 1897, the Badische Anilin und Sodafabrik (BASF) in Ludwigshafen produced the synthetic dye in large quantities, with the consequence being that the natural indigo disappeared completely from the market. *(Holzmann, Wangelin, 2009)* It was only during the 1980s that Wolfgang Feige from Neudietendorf in Thuringia rediscovered the woad plant. A woad plant as well as a woad farmer in a blue costume are depicted in the emblem of his hometown Neudietendorf. Wolfgang Feige primarily wanted no more than to measure the sense of the depicted objects in the emblem but went on to research for the next 20 years about Isatis tinctoria. *(Fischer, 1997); (Feige, 2019)* According to historical sources, Wolfgang Feige can be placed amongst Hippocrates, Pliny the Elder, Caesar, Charlemagne, and others who have also conducted research about the plant and its beneficial assets and values. *(Müllerott, 1989)* Woad was used throughout the Middle Ages in England and mainly imported from Europe. In the 16th century, however, the cultivation area for woad increased considerably. This was probably due to the fact that deliveries of woad from Europe became unreliable and expensive. *(Roberts, 2019)* Amid 1377, Coventry was the fourth largest city in England and because of the flourishing centre of the wool and cloth trade, the phrase "as true as Coventry Blue" was created, considering the blue cloth dyed in Coventry was known as colourfast. Later during the 1500s, growing woad was strictly regulated in England, at a time of

food shortages that led to the famine of 1586. Fearing that the amount of land being used for woad and not for grain was too much, Queen Elizabeth I issued a "Proclamation against the sowing of woad" on 14 October 1585. She declared that the “breaking up and sowing of the most fertile soil with woad was a major cause for complaint. No one should break the ground for the present or sow woad within four miles of a market or clothing town or within eight miles of a queen's house.” This was adjusted in 1587 to permit no greater than 40 or 60 hectares of woad in a parish and no more than 20 hectares sown annually by one person. Only around 1932, UK farms had ceased to grow woad commercially. *(Roberts, 2019)*

With the purpose of proving the utility of the dye plant presently, it is inevitable to study its different application possibilities. Dyer's woad could be utilised in numerous ways. The research project is a comprehensive analysis of woad in relation to its diverse use and potential business ideas and products.

Plants as colourants go back a long way in human history to cave painting, which is one of the oldest testimonies. In medieval Europe, woad was the only source of blue coloration. In addition to its use as a dye plant, woad can also be processed into various ecological building materials such as paint, impregnation for wood, stone and clay, and thermal insulation. Woad can also be used for cosmetic and medical purposes *(Fischer, 1997)*. Ancient Asian and Roman sources report of the healing and nourishing effects. *(Müllerott, 1989)* Another characteristic feature of woad, which is a cruciferae, is the content of glucosinolates. The degradation of the glucosinulates sets free chemical compounds with herbicidal, fungicidal, bactericidal, nematocidal, and insecticidal effects *(Kaiser-Alexnat, 2014)*. The usage of the germination inhibitory effect could be used eventually in ecological agriculture for specific applications like a biological herbicide or pesticide.

For this project, experts of woad, from cultivation to business experience and scientific knowledge, were interviewed about their personal relation to the plant. The interviews were conducted following a guideline of semi-structured interviews about their opinions of the possible success of woad in different business areas. Due to the many possible applications of the woad plant, each expert has experience in solely specific fields, which causes a variety of opinions. However, the findings from the one-on-one interviews also generated ideas about further possibilities, challenges, problems and approaches to solutions.

3.2 JUSTIFICATION, SIGNIFICANCE AND PREVIOUS RESEARCH

The agricultural market in Germany is changing to more ecological production. The transformation needs, above all else, people who actually make something for the transformation. The number of these types of people is growing. Beginning with the customers, who are constantly getting eco-friendlier and innovative entrepreneurs who are developing new approaches in agriculture, production and trade. Also, visionary people in politics and administration, who are able to recognise and exploit bio-potential *(Moewius, Röhrig, 2019).* The vision of new ecological products with woad could be a chance for the modern agriculture, since the agriculture is in a period of tremendous change. The cultivation of dye plants has been of great importance for domestic agriculture for centuries. But as already mentioned, the cultivation progressively decreased due to growing imports of natural dyestuffs and the production of synthetic dyestuffs. Today, the demand for natural dyestuffs in the textile sector is rising again and there are at least 1,000 hectares of dyer plants cultivated. *(Pflanzen für Industrie und Energie, 2019)* This is due in particular to a changing consumer behaviour, through which natural dyestuffs are used, among other things, in the dyeing of food and beverages and in the cosmetics industry. There is also more interest in vegetable pigments in the leather industry, where applications range from handbags to furniture leather to car seats. Plant dyes are available in specialist artists' markets and are used in the fields of monument preservation and high-quality art painting. *(Pflanzen für Industrie und Energie, 2019)*

The Technology and Promotion Centre (Technologie- und Förderzentrum TFZ) held a conference in Straubing (Bavaria, Germany) in March 2019 with the purpose of presenting cultivated plants to the agricultural sector and to the advisory services sector that, in addition to their potential for energetic and material utilisation, also contribute to diversity in the field. *(Mehr Biodiversität durch Nachwachsende Rohstoffe, 2019)* The conference marked the start of the "Biodiversity Years" 2019 and 2020, in which the Bavarian Ministry of Agriculture will focus its work on this key topic. The conclusion of the TFZ is that more habitat diversity is required in the agricultural landscape, which can be achieved through the targeted design of crop rotations, the cultivation of permanent crops and flower mixtures for energy use and the increased cultivation of renewable raw materials, amongst others. All in all, renewable raw materials offer the opportunity to combine ecological advantages with arable

production. Dr. Maendy Fritz, Head of Raw Material Plants at TFZ, has the credo: "Ecology and economy can go hand in hand". She presented several energy crops that can be grown as crop rotation supplements and on land with lower production suitability. *(Mehr Biodiversität durch Nachwachsende Rohstoffe, 2019)*

The energy and raw material plants tested at TFZ are intended to increase the diversity of biodiversity in the cultural landscape by creating new or keeping open ecological niches. In the “Bavarian Biodiversity Years 2019 and 2020”, the TFZ supports events on relevant topics and advises on concrete implementation. Dyer’s woad fits in this context, because it is an example of an ecological niche, a renewable raw material, and economic incentives could be created in various fields.

The size of woad can be up to 140cm and the extraction of raw materials from every part of the plant is possible. This could create a sustainable production process if all its different sections are merchantable. Through research by Wolfgang Feige, the following findings were obtained in numerous experiments in the 1980s and 1990s: The medical applications range from dried leaves, which can be processed into a medicinal tea, extracts from the plant for healing creams, to cosmetics. In addition, the building sector offers enormous potential for woad, because ecological building materials such as impregnating or wood preservatives as well as insulating materials, paints, varnishes and lacquers can be produced from different parts of the plant.

The products formerly manufactured by the Thüringer Waid Verarbeitungs GmbH (TWV) in Neudietendorf were free of toxic or harmful vapours, chlorinated or persistent additives and were not flammable (Müller, 1998). By adding appropriate colour pigments, different colour shades can be achieved in the paints. Woad extract can also be successfully used for paper and leather restoration. The extract contains the necessary binding agent, has a fungicidal effect and can be dyed in the colours specified by the original (Müller, 1998) In addition, it is even possible to produce a woad liqueur (woad bitter) from the roots of the plant (Feige, 1985). Renate Kaiser-Alexnat from the Julius Kühn Institute in Darmstadt also investigated the effect of the woad in plant protection with preliminary experiments. The fruits of woad release allelopathic substances when they rot in the soil, which can have an inhibitory effect on the germination of the seeds. Furthermore, Renate Kaiser-Alexnat created the private homepage "Institute for dye plants", which is a platform for all dyeing plants and

natural dyestuffs. The most prominent plant on the website is woad and literature references including contemporary information about the plant are updated regularly.

In England, on the Mythe near Tewkesbury in Gloucestershire and Surrey, woad has been growing wild for at approximately 200 years. The popularity of reenactment companies like SPINDIGO (Sustainable Production of Plant-derived Indigo) in 2004, an European project for the production of natural indigo for the European retail market and recent films such as King Arthur (2004) and Braveheart (1995) with Picts, Celts, Romans and Scots developing interest and awareness in the use of woad as a dye. *(Roberts, 2019)* And recently, English woad was produced in Norfolk (Woad-Inc) by Ian and Bernadette Howard. Woad-Inc is the trade name of a Norfolk farmer who has diversified into woad cultivation natural for indigo pigmentation. *(Howard, Howard, 2019)*

This research project is also underpinned by the network project from the Ökotrend Projekt und Marketing GmbH for dyers plants like woad, reseda and madder, which started in April 2019. The aim of the project is to build a network of actors for the preservation and use of the potentials of versatile useful plants. *(Waid, Resede, Krapp & Co – Ökotrend, 2019)*

The goals of the project of the Ökotrend Projekt und Marketing GmbH are:

- Establishment of a network consisting of agricultural and horticultural enterprises as well as practitioners and scientists involved in the cultivation and use of dyeing plants
- Preservation of traditional colouring plants (part of the "red list of endangered indigenous crops in Germany") and diversification of cultivation by extending crop rotation which contributes to improve the biodiversity
- Network for bundling individual initiatives, exploiting synergy effects and generating new impulses
- Preparation of the establishment of value chains based on already existing, well-known research and in combination with other value chains (e.g. fiber plants, building material, food, pharmaceuticals, cosmetics)
- Preparation of activities for further research and exploitation of the potentials of dyeing plants

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The Ökotrend Projekt und Marketing GmbH from Erfurt are expanding their portfolio with this project through associations and companies in Thuringia. Neighbouring regions are supported in networking around dyeing plants and in preserving and exploiting the potential of these versatile crops. The project has 12 collaborators and the Thüringer Landesamt für Landwirtschaft und Ländlichen Raum TLLLR from Jena is an associated partner. Furthermore, the project is subsidised by the Thüringer Aufbaubank in accordance with the funding guideline "Förderung der Zusammenarbeit in der Land-, Forst- und Ernährungswirtschaft in Thüringen" (LFE) (promotion of cooperation in agriculture, forestry and food management in Thuringia). *(Waid, Resede, Krapp & Co – Ökotrend, 2019)*

Since 1994, in France in Gers, Lectoure close to Toulouse "Bleu-de-Lectoure" are working with woad (pastel) and in particular, cultivate the plant, extract the pigment and use it for of fine arts, decoration and textiles. Bleu de Lectoure is manufacturing and dyeing everything completely natural, with a range of products being for instance paint, cosmetics, clothing, linen. Close to Toulouse, an historically important city for woad, Graine de Pastel, another French company is using the dermatologic properties of the woad plant for their cosmetical products. It is stated on their website that the scientific term, Isatis tinctoria, derives from the Greek word "isado", which means "to heal". The woad seeds have been protected in France by the Conservatoire National des Plantes Médicinales over the last centuries. About 25 years ago, woad has been cultivated in this area and the seeds are picked up and cold pressed. One ton of raw woad seeds is necessary to acquire 40 litres of the base materials used for the cosmetical products of Graine de Pastel. *(Graine de Pastel, 2019)*

The following table was compiled to show the large number and variety of previous research about the woad plant. Most of the research in the table is about medicinal research, but there is also general research (for example, the cultivation of woad or where the plant is still growing wild in nature). *(Bleu de Lectoure, 2019)*

This table showing a multitude of existing literature about woad (Isatis tinctoria), is another indicator for the scientific importance and the potential of the plant.

TABLE 1: LITERATURE FOR THE EXPLORATION OF BUSINESS IDEAS OF THE WOAD PLANT

Title of study	Research explanation
Before 1990	
Young, J. A., & Evans, R. A. (1971). Germination of dyers woad. Weed Science, 19(1).	Germination of dyers woad
Gelius, R. (1980). Zur Geschichte des europäischen Waidindigos. (L'histoire du pastel en Europe). NTM. Schriftenreihe für Geschichte der Naturwissenschaften Technik und Medizin Leipzig	History of the European woad indigo
Honda, G., Tosirisuk, V., & Tabata, M. (1980). Isolation of an antidermatophytic, tryptanthrin, from indigo plants, Polygonum tinctorium and Isatis tinctoria. Planta medica, 38(03), 275-276.	Isolation of an antidermatophytic, tryptanthrin, from indigo plants, Polygonum tinctorium and Isatis tinctoria
Feige, W. (1985). Wiederentdeckung der Waidpflanze (Isatis tinctoria) und Verwendung: Forschungsbericht / VEB Chemiekombina: Bitterfeld	Rediscovery of the woad plant and its application
Eisenhardt, K. M. (1989) Building Theories from Case Study Research. Academy of Management Review. 14(4): 532-550	Building Theories from Case study research
Müllerott, H. (1989). Quellen zum Waidanbau in Thüringen: e. katalogmäßige Zusammenstellung von Quellen als Voraussetzung für eine Neubearbeitung des Gesamtthemas „Waid" in Vorbereitung von Publikationen u. Ausstellungen (Doctoral dissertation).	Sources for woad farming in Thuringia
Seifert, K. (1989). Inhaltsstoffe von Isatis tinctoria L.: Literaturzusammenstellung. Institut für Biochemie der Pflanzen. Halle	Ingredients of Isatis tinctoria L.
1990-2000	
Dewey, S. A., Price, K. P., & Ramsey, D. (1991). Satellite remote sensing to predict potential distribution of dyers woad (Isatis tinctoria). Weed Technology, 5(3), 479-484.	Satellite remote sensing to predict potential distribution of dyers woad (Isatis tinctoria)
Kaiser, R.(1993): Dye plants, their cultivation and use in Germany. In: Marshall, G., K. Svoboda (Eds.): Proceedings of an EC workshop „The production and	Dye plants as minor crop

impact of specialist minor crops in the rural community". 27.-28. April 1993, Brüssel, Belgien, 75-83, 1993.	
Evans, J.O., Dewey S.A., (1994). Dyer's Woad. In: Sheley, R. L. (1994). The identification, distribution, impacts, biology and management of noxious rangeland weeds.	Dyer's woad overall context
Hartleb, I. (1994). Inhaltsstoffe von Isatis tinctoria L. und Verbascum songaricum Schrenk (Doctoral dissertation).	Ingredients of Isatis tinctoria
Kaiser-Alexnat, R.(1994): Screening von Farbstoff-liefernden Pflanzen. Beiträge zur Waidtagung 6, 5-11, 1994.	Screening of the dye plants
Fischer, F. (1997). Das blaue Wunder: Waid: Wiederentdeckung einer alten Nutz-und Kulturpflanze. vgs.	Rediscovery of an old crop
2000-2010	
Danz, H., Stoyanova, S., Wippich, P., Brattström, A., & Hamburger, M. (2001). Identification and isolation of the cyclooxygenase-2 inhibitory principle in Isatis tinctoria. Planta medica, 67(05), 411-416.	Identification and isolation of the cyclooxygenase-2 inhibitory principle in Isatis tinctoria
Fréchard, A., Fabre, N., Péan, C., Montaut, S., Fauvel, M. T., Rollin, P., & Fourasté, I. (2001). Novel indole-type glucosinolates from woad (Isatis tinctoria L.). *Tetrahedron Letters*, *42*(51), 9015-9017.	Novel indole-type glucosinolates from woad (Isatis tinctoria L.).
Maugard, T., Enaud, E., Choisy, P., & Legoy, M. (2001). Identification of an indigo precursor from leaves of Isatis tinctoria (Woad). *Phytochemistry*, *58*(6), 897-904. doi:10.1016/s0031-9422(01)00335-1	Identification of an indigo precursor from leaves of Isatis tinctoria (Woad)
Danz, H., Baumann, D., & Hamburger, M. (2002). Quantitative determination of the dual COX-2/5-LOX inhibitor tryptanthrin in Isatis tinctoria by ESI-LC-MS. Planta medica, 68(02), 152-157.	Quantitative determination of the dual COX-2/5-LOX inhibitor tryptanthrin in Isatis tinctoria by ESI-LC-MS
Hamburger, M. (2002). Isatis tinctoria–from the rediscovery of an ancient medicinal plant towards a novel anti-inflammatory phytopharmaceutical. Phytochemistry Reviews, 1(3), 333.	Isatis tinctoria–from the rediscovery of an ancient medicinal plant towards a novel anti-inflammatory phytopharmaceutical
Ronald Steriti, N. D. (2002). Nutritional support for chronic myelogenous and other leukemias: a review of the	Nutritional support for chronic myelogenous and other leukemias:

scientific literature. *Alternative medicine review*, *7*(5), 404-409.	a review of the scientific literature
Oberthür, C., Heinemann, C., Elsner, P., Benfeldt, E., & Hamburger, M. (2003). A comparative study on the skin penetration of pure tryptanthrin and tryptanthrin in Isatis tinctoria extract by dermal microdialysis coupled with isotope dilution ESI-LC-MS. Planta medica, 69(05), 385-389.	A comparative study on the skin penetration of pure tryptanthrin and tryptanthrin in Isatis tinctoria extract by dermal microdialysis coupled with isotope dilution ESI-LC-MS
Eisenbrand, G., Hippe, F., Jakobs, S., & Muehlbeyer, S. (2004). Molecular mechanisms of indirubin and its derivatives: novel anticancer molecules with their origin in traditional Chinese phytomedicine. *Journal of cancer research and clinical oncology*, *130*(11), 627-635.	Molecular mechanisms of indirubin and its derivatives: novel anticancer molecules with their origin in traditional Chinese phytomedicine
Hamburger M. (2004), De novo Entwicklung von Phytopharmaka am Beispiel von Färberwaid (Isatis tinctoria L.) (De novo development of phytopharmaceuticals – a case study of woad (Isatis tinctoria L.). In: "Proceedings of the Fachtagung für Arznei- und Gewürzpflanzen 2004", Jena, Germany, September 7-9, 2004, pp. 71-73.	De novo development of phytopharmaceuticals – a case study of woad (Isatis tinctoria L.)
Heinemann, C., Schliemann-Willers, S., Oberthür, C., Hamburger, M., & Elsner, P. (2004). Prevention of experimentally induced irritant contact dermatitis by extracts of Isatis tinctoria compared to pure tryptanthrin and its impact on UVB-induced erythema. Planta medica, 70(05), 385-390.	Prevention of experimentally induced irritant contact dermatitis by extracts of Isatis tinctoria compared to pure tryptanthrin and its impact on UVB-induced erythema
Oberthür, C. (2004). Indolische Sekundärmetabolite in Isatis tinctoria L.-Hautpenetration von Tryptanthrin und saisonale sowie prozessbedingte Veränderungen der Inhaltsstoffmuster (Doctoral dissertation).	Indolic secondary metabolites in Isatis tinctoria L. skin penetration of tryptanthrine and seasonal as well as process-related changes in the ingredient patterns
Oberthür, C., Schneider, B., Graf, H., & Hamburger, M. (2004). The elusive indigo precursors in woad (Isatis	The elusive indigo precursors in woad

tinctoria L.)–identification of the major indigo precursor, isatan A, and a structure revision of isatan B. Chemistry & biodiversity, 1(1), 174-182.	(Isatis tinctoria L.)–identification of the major indigo precursor, isatan A, and a structure revision of isatan B.
Oberthür, C., & Hamburger, M. (2004). Tryptanthrin content in Isatis tinctoria leaves-a comparative study of selected strains and post-harvest treatments. planta medica, 70(07), 642-645.	Tryptanthrin content in Isatis tinctoria leaves-a comparative study of selected strains and post-harvest treatments
Oberthür, C., Graf, H., & Hamburger, M. (2004). The content of indigo precursors in Isatis tinctoria leaves—a comparative study of selected accessions and post-harvest treatments. Phytochemistry, 65(24), 3261-3268.	The content of indigo precursors in Isatis tinctoria leaves—a comparative study of selected accessions and post-harvest treatments
Oberthür, C., Jäggi, R., & Hamburger, M. (2005). HPLC based activity profiling for 5-lipoxygenase inhibitory activity in Isatis tinctoria leaf extracts. Fitoterapia, 76(3-4), 324-332.	HPLC based activity profiling for 5-lipoxygenase inhibitory activity in Isatis tinctoria leaf extracts
Condurso, C., Verzera, A., Romeo, V., Ziino, M., Trozzi, A., & Ragusa, S. (2006). The leaf volatile constituents of Isatis tinctoria by solid-phase microextraction and gas chromatography/mass spectrometry. Planta medica, 72(10), 924-928.	The leaf volatile constituents of Isatis tinctoria by solid-phase microextraction and gas chromatography/mass spectrometry
Galletti, S., Barillari, J., Iori, R., & Venturi, G. (2006). Glucobrassicin enhancement in woad (Isatis tinctoria) leaves by chemical and physical treatments. Journal of the Science of Food and Agriculture, 86(12), 1833-1838.	Glucobrassicin enhancement in woad (Isatis tinctoria) leaves by chemical and physical treatments
Hamburger, M., Rüster, G. U., & Melzig, M. F. (2006). HPLC based activity profiling for inhibitors of human neutrophil elastase in Isatis tinctoria leaf extracts. Natural Product Communications, 1(12), 1934578X0600101207.	HPLC based activity profiling for inhibitors of human neutrophil elastase in Isatis tinctoria leaf extracts
Recio, M. C., Cerdá-Nicolás, M., Potterat, O., Hamburger, M., & Ríos, J. L. (2006 a). Anti-inflammatory and	Anti-inflammatory and antiallergic activity in vivo of lipophilic Isatis

antiallergic activity in vivo of lipophilic Isatis tinctoria extracts and tryptanthrin. Planta medica, 72(06), 539-546.	tinctoria extracts and tryptanthrin
Recio M.C., Cerdá-Nicolás M., Hamburger M., Rios J.-L., (2006 b) Activity of lipophilic Isatis tinctoria extracts in adjuvans-induced arthritis in mice. Planta Med. 72, 715-720.	Activity of lipophilic Isatis tinctoria extracts in adjuvans-induced arthritis in mice
Stirk, W. A., Thomson, S. V., & van Staden, J. (2006). Effect of rust-causing pathogen (Puccinia thlaspeos) on auxin-like and cytokinin-like activity in dyer's woad (Isatis tinctoria). Weed science, 54(5), 815-820.	Effect of rust-causing pathogen on auxin-like and cytokinin-like activity in dyer's woad
Halle, I., Thomann, R., Friebel, H., Gruen, M., Henning, M., Köhler, P., & Flachowsky, G. (2008). Influence of woad (Isatis tinctoria) and ginkgo (Ginkgo biloba) on growth of broiler chickens. *Proceedings Of The Society Of Nutrition Physiology - Berichte Der Gesellschaft Für Ernährungsphysiologie*, 78. Retrieved from https://www.openagrar.de/receive/fimport_mods_00001649	Influence of woad (Isatis tinctoria) and ginkgo (Ginkgo biloba) on growth of broiler chickens
Kaiser-Alexnat, R. (2008). Isatis tinctoria L. - Färberwaid. Datenblatt, Institut für Färbepflanzen, seit 2008.	Data sheet of woad
Kaiser-Alexnat, R. (2008). Färberwaid (Isatis tinctoria L.): Perspektiven einer vielseitigen Nutzpflanze. Nachrichtenblatt des Deutschen Pflanzenschutzdienstes 60 (5), 97-103, 2008.	Different perspectives of woad (herbizide)
Schmatz, R., Schütze, K., Ormerod, C., & Biertümpfel, A. (2008). Versuche mit Herbiziden in Waid Isatis tinctoria L. in Thüringen	Herbicide tests in Isatis tinctoria L. in Thuringia
2010-2019	
Meier, B., Wemmer, D., Kneip, B., Simões-Wüst, A. P., Saltzwedel, G., Herr, I. S., ... & Locher, A. (2012). Expertengespräch: Forschung und Entwicklung in der Phytotherapie–Teil 1. Schweizerische Zeitschrift für Ganzheitsmedizin/Swiss Journal of Integrative Medicine, 24(5), 266-268.	Research and development in the phytotherapie
Biertümpfel, A. Stolte, H. Wenig, B. Adam, L. (2013). Fachagentur Nachwachsende Rohstoffe e.V. Färbepflanzen: Anbau, Farbstoffgewinnung und Färbeeignung. (www.nachwachsende-rohstoffe.de)	Cultivation and dye extraction and dyeing suitability of woad
Hoppe, B., Biertümpfel A., Hammer M., Reinhold G., Vetter A. (2013). Handbuch des Arznei- und Gewürzpflanzenbaus, Band 5, Arznei-und Gewürzpflanzen	Handbook of medicinal and spice plant cultivation

von L - Z, Verein für Arznei- und Gewürzpflanzen Saluplanta e.V., Bernburg, Deutschland.	
Kaiser-Alexnat, R. (2013): Färberwaid - Potentiale einer außergewöhnlichen Pflanze. Beitrag zur 7. Waidtagung in Pferdingsleben am 22. und 23. Juni 2013, Band 8, 51-66, 2013.	Different potentials of woad
Kaiser-Alexnat, R., J. Freese (2013): Waidanbau auf einem Rindermastbetrieb. LandInForm Spezial „Alte und neue Kulturpflanzen zwischen Wertschöpfung und Umweltleistung“, Heft 4, 27, 2013.	Woad on cattle farm
Kaiser-Alexnat, R.: Färberwaid (2013): Eine alte Kulturpflanze neu entdeckt. LandInForm Spezial „Alte und neue Kulturpflanzen zwischen Wertschöpfung und Umweltleistung“, Heft 4, 28-29, 2013.	Woad as a crop for the environment and the value chain
Guldbrandsen, N., Kostidis, S., Schäfer, H., De Mieri, M., Spraul, M., Skaltsounis, A. L., ... & Hamburger, M. (2015). NMR-Based metabolomic study on Isatis tinctoria: Comparison of different accessions, harvesting dates, and the effect of repeated harvesting. Journal of natural products, 78(5), 977-986.	NMR-Based metabolomic study on Isatis tinctoria
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Alternative Medicine, E. B. C. (2018). Expression of Concern on “Modes of Antiviral Action of Chemical Portions and Constituents from Woad Root Extract against Influenza Virus A FM1”. Evidence-Based Complementary and Alternative Medicine, 2018.	Woad root extract against influenza Virus A
Taviano, M. F., Filocamo, A., Ragusa, S., Cacciola, F., Dugo, P., Mondello, L., ... & Melchini, A. (2018). Phenolic profile, antioxidant and cytotoxic properties of polar extracts from leaves and flowers of Isatis tinctoria L.(Brassicaceae) growing in Sicily. Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology, 152(4), 795-803.	Phenolic profile, antioxidant and cytotoxic properties of polar extracts from leaves and flowers of Isatis tinctoria L.

(Source: own figure)

3.3 RESEARCH PROBLEM AND RESEARCH PURPOSE

The problem statement: There are a few attempts for research projects about woad and its possible applications, but there has not been a significant and successful break-through in the market.

To this day, many scientists have developed a series of individual research elements, which form the basis for further research and the results of which must be implemented in production and products.

The purpose statement: The goal of this qualitative study was to examine, from the perspective of woad experts and experts of dye plants, which business ideas could be successful and how they can be realised. The purpose of the study is therefore the provision of a profounder understanding into already established and not yet discovered possibilities from the perspective of experts who have researched about Isatis tinctoria L. and the availability of academic resources. The results should identify new methods and approaches to evolve business ideas of the woad plant.

The objective of this study was to have an in-depth look into the different applications of woad and what the researchers think about the possibilities and the future in these markets in general. The findings shoud:

- Point out the most important and promising applications of woad
- Identify the various markets in which woad could be a product
- Defining the future orientations and a clear approach to which all potential parties can commit themselves.

3.4 RESEARCH QUESTIONS AND OBJECTIVES

The aim of this research is to establish a greater apprehension of the type of feasible applications for woad and acquire business position and ideas for woad as a versatile produce.

The research questions were addressed to the woad expert to gain a greater understanding of the woad plant and its possibilities:

Research questions:

1. What are the typical uses of woad as an ecological building material?

2. How can woad be used for other functions?
3. What are the competitive advantages of woad in the market?

The research objectives aim to obtain answers to the research questions. They are designed clearly and meaningful to narrow down and focus the research on the most relevant findings.

Research objectives:

1. To review the typical uses of woad as an ecological building material.
2. To identify the other functions of woad.
3. To investigate the applications of woad in different markets.
4. To explore the factors influencing the competitive advantage of woad in the market.

3.5 RESEARCH APPROACH

The research project represents an inductive approach using qualitative research to examine the woad plant with possible applications and to have an insight of business ideas.

The data was collected with semi-structured interviews with woad experts, to gather information of the attitudes, expectations, success factors and obstacles, which were gained by different researches, experiences and ideas. For the interviews eight experts were purposely chosen and the data through collected conversational communication. The experts differ from farmer with plant cultivation experience, to entrepreneurs with business experience, to scientist, who have done research with Isatis tinctoria.

For ensuring personal in-depth answers combined with body language the participants were interviewed individually and in person. Semi-structured interviews and predefined questions were essential for developing a conversation with the interviewee. For creating a conversation based on each participants response open-ended questions were asked, to get more detailed answers and information. In order to avoid the researcher bias, an impartial position of the interviewer was mandatory for the interview process.

The interviews were audio-recorded and short notes were written during each interview, not only for a more detailed report but moreover to record further suggestions of research participants. Woad experts are difficult to find, therefore snowball sampling was used to identify experts for this research. *(Snowball Sampling, 2014)*

The goal was to accomplish the point of saturation in terms relevant new data from interviews, in which additional would not deliver a better insight. The audio-recorded interviews were first transcribed and after that the collected data analysed on the basis of coding technique. Deriving from the analysis of the data a hypothesis could be formed.

The basis for the overall results of this research project is the information and data acquired through the interviews.

4 LITERATURE REVIEW

4.1 INTRODUCTION

The literature review consults the findings of up to date literature about Isatis tinctoria and in particular for the exploration of five main topics for business ideas of the woad plant: woad blue, buildings materials, medicine and cosmetics, natural plant protection and food for humans as well as animal nutrition. The goal is to review and explore the literature for business ideas of woad in terms of key theories, concepts and ideas about these five main topics. In this context also the main questions surrounding the topic have been taken into consideration and what problems have been addressed to date.

In the introduction of this thesis there is a list of the existing literature about woad temporally structured, which already shows how many research projects have been conducted in the last few decades. Nevertheless, there is a gap in the literature of business ideas of woad and thus, for the achievement of a theoretical underpinning of the research. Consequently, the business ideas are discussed more generally and reflected which of these might be applied to products. Only the most relevant and useful literature was observed for the attainment of satisfying the research questions and research objectives.

For several centuries, woad determined the economic life in Thuringia. Many farmers in the region earned their living by growing, cultivating, harvesting and first processing woad. The bale woad produced by the farmers was sold to woad squires and further processed by woad farmhands so that it could be marketed mainly in the cities as a textile dye. The manufactories of that time only had the blue dyeing of textiles as their purpose for the cultivation and processing of this dyeing plant. Currently, only a few businesses sell products with woad on the market. These products range from woad dyed textiles to medical and cosmetical products as well as ecological buildings materials. Raw materials can be extracted from each section of the one and a half metre plant. The two tables underneath give an overview and summary which part of the plant can be used for what business area and product.

TABLE 2: CONSTRUCTION PRODUCTS AND MATERIALS

Construction products/materials				
Part of plant	**Transitional form**	**Feature**	**Application**	**Product examples**
Leaves	Juice	Insecticide, fungicide, flame retardant	Wood and building protection	Impregnating agent for wood, stone and mineral plasters
Leaves	Dripping water out of mush preparation	Binding force, flame retardant	Binder	Paints, lacquers, glaze (scumble)
Stem, leave mush, seed-shredded mass	Pressed out mass, fibres	Binding force, flame retardant	Thermal insulation	Loose cellulose insulation, thermal insulation products
Seeds	Oil	Binding force	Binder	Paints, lacquers, glaze (scumble)
Leaves	Fermented mush; dried or powdered	Tinting & colouring	Dyeing coating or colouring additive	Paints, lacquers, varnishes (scumble), plaster

(Source: adapted from Holzmann, G., & Wangelin, M. (2009). Natürliche und pflanzliche Baustoffe. Wiesbaden: Vieweg+ Teubner)

TABLE 3: MEDICINE AND COSMETICS, FOOD AND DYE

Medicine & Cosmetic				
Part of plant	**Transitional form**	**Feature**	**Application**	**Product examples**
Seeds & leaves	Woad juice pressed or fermented; woad oil, leaf pulp	Bactericide, fungicide, film-forming agent	Wound healing, skin fungus control	Ointment, cream, shampoo, bath additives
Leaves	Dried	Healing effect with suspected effect against allergies and cancer	Gastrointestinal disorders, spleen problems	Tea
Food				
Seeds	Oil	Edible	Food	Oil
Flowers & flower buds & blossom	Nectar, pollen grains	Pleasant smell	Aroma	Fragrances, honey, vegetable
Dye				
Leaves & roots	Fermented pulp; dried or powdered	Tinting & dyeing	Textile dyeing, painting	Textile dyeing, (black, brown, blue, green), painting colours

(Source: adapted from Holzmann, G., & Wangelin, M. (2009). Natürliche und pflanzliche Baustoffe. Wiesbaden: Vieweg+ Teubner)

4.2 OVERVIEW OF THEORY AND CONTEXT FOR STUDY

WOAD BLUE

Blueprinting was declared an immaterial world cultural heritage in November 2018 by the nationwide directory of Intangible Cultural Heritage (World Cultural Heritage Blueprint Erfurt Blueprint Manufactory Erfurt in the Dürrerhaus). Maria Böhmer, the Minister of State at the Federal Foreign Office, said: "I warmly welcome this joint nomination of five European countries (Germany, Austria, Czechia, Slovakia and Hungary). The UNESCO Convention encourages the joint protection of traditions across linguistic and national borders. This promotes understanding and peace, furthermore it can also be used as a model for different places around the world. A successful entry on the UNESCO list will also once again strengthen the cooperation and networking of all people working in blueprinting in our countries". *(Bundesweites Verzeichnis Immaterielles Kulturerbe, 2019)*

The cultivation of dye plants has been of great importance for domestic agriculture for centuries. Due to growing imports of natural dyestuffs and the production of synthetic dyestuffs, their cultivation progressively declined. Today, the demand for natural dyestuffs in the textile sector is rising again: Dyer plants are cultivated on almost 1,000 hectares. The changing consumer behaviour is, in particular, the main reason for the increasing demand. Natural dyes are used, for example, in the colouring of food and beverages and in the cosmetics industry. The leather industry is also showing more interest in vegetable pigments: Possible applications range from handbags and furniture leather to car seats. Plant dyes are available in specialist artists' markets and are used in the fields of monument preservation and high-quality art painting.

Historically and for medieval business, the most important ingredient of the woad plant is the dark blue dye indigo, which is present in the plant only as a colourless precursor (Indican). By fermentation of the crushed leaves first indoxyl is formed, which is converted to indigo by the absorption of atmospheric oxygen. The blue colour only appears when, for instance, the dyed textiles are dried in the air. An example for a German business nowadays using woad leaves for dyed textiles is the woad manufactory “Erfurter Blau” on the famous Krämerbrücke in Erfurt. The products are manufactured in their own studio in Erfurt, but also in cooperation with other craftsmen and designers. Rosanna Minelli, produces and dyes scarves made of silk or wool and

living room textiles made of cotton with woad blue. *(Erfurter Blau, 2019)* Partly she grows her own woad in a field on the outskirts of Erfurt and therefore, directly obtains the dye for her products. Partly, she gets the woad from the seed production “Saatzucht Rose” in Erfurt. In “Saatzucht Rose”, ornamental, medicinal and spice plants as well as vegetables for seed production are cultivated on over 100 hectares of farmland with first-class loess soil and favourable climatic conditions. The focus is not only on profit interests, but also on species diversity. Plant manager Annegret Rose attaches great importance to ensuring that everything is produced at the Erfurt site. It is a difficult undertaking to counter the gigantic market power of large corporations such as Bayer-Monsanto and also to observe the Demeter principle of biodynamic cultivation, which goes far beyond the normal EU organic regulations. *(Holzmann, 2017)*

BUILDING MATERIAL

The processing of a special woad mixture, developed by Wolfgang Feige, makes wood impregnation, stone and paper conservation possible. Additionally, as a result of his research, woad could be developed into corrosives, glazes and paints for wood, stone and plaster. In 1991, the "Thüringer Waid Verarbeitungs GmbH" (TWV) as well as the "Thüringer Waid Forschungs GmbH” (TWF) were founded and from this point on researched, manufactured and the following products were distributed: Thüringer Waid wood primer, Thüringer Waid thatched roof impregnation with fire retardant effect, Thüringer Waid masonry impregnation, Thüringer Waid anti-moss, Thüringer Waid deck paint for wood coatings, Thüringer Waid wood varnish. *(Höhn, 1991)* As a transparent wood care product for all wooden parts (from half-timbered houses to windows, doors and garden fences) you can use wood glaze, which is made from fermented woad extracts. In addition, it can be used to restore the colour of old wood or to refine new wood to restore its natural grain. All of these building materials can still be purchased online on an ecological building material website. The products are produced like the ones before and called “Thüringer Waid” out of Thuringian woad, but the Thüringer Waid Verarbeitungs GmbH does not exist anymore. The products are completely natural wood preservatives, which can be used for raw and old woods. After the woad primer, a coloured glaze or topcoat can also be used on the same base. The company promises that the wood is protected against weathering for 10-15 years. The following products can be obtained from their range: Thüringer Waid wood primer, Thüringer Waid thatched roof impregnation with fire retardant effect, Thüringer Waid

masonry impregnation, Thüringer Waid anti-moss, Thüringer Waid deck paint for wood coatings, Thüringer Waid wood varnish. *(Ökologischer Baustoffhandel - Thüringer Waid, 2019)*

Due to its insecticidal and fungicidal effect against mould and sponges, the woad extract is suitable for preventive wood treatment. The wood glaze is a pure natural product and environmentally friendly, so that it can be applied as a wood coating in many areas. *(Holzmann, Wangelin, 2009)*

The woad impregnation can take place entirely naturally from the woad plant. The binders are made from the vital oils of the plant itself. With its insecticide and fungicide effect, this deeply impregnating and solidifying primer can be used for absorbent, colourless, dry surfaces indoors and outdoors as well as for all wooden parts such as lattice girders, windows or doors. *(Holzmann, Wangelin, 2009)*

Moreover, natural oil, base and topcoats can be obtained from the fermented extract of woad plants and can be utilised for interior and exterior paints. The solvent-free product is resistant to weathering and light. The fields of application range from environmentally friendly restoration paints on old wood to preventive wood treatment due to its insecticidal and fungicidal effect against mould and sponges. *(Feige, 1985)*

During the last 30 years, plaster including stone and wood preservatives from the Thuringian woad products have been used to restore many buildings in Thuringia. *(Macias, 1998)*

A joint project was established in Thuringia from April 1996 until end of June 1999 by the German Federal Foundation for the Environment (DBU) financially supported a project with 910.801,04 DM. The project was supported by Thüringer Waidverarbeitungs GmbH (TWV), the Thuringian State Institute for Agriculture (TLL) and the Hans Knöll Institute for Drug Research in Jena (HKI). The aim and purpose of the project was to optimise the active ingredients of the woad plant, which can be used in wood and building protection due to their fungicidal and insecticidal effectiveness. However, since cultivation and processing technology were still immature, there were a number of problems with the quality and quantity of the wood impregnating agent. Already in the 1990s there was an increasing demand for ecological paints, which is why the development of new marketable and environmentally friendly paints based on woad, was seen as an alternative to chemical wood preservation. The project was

divided into three parts: the first part concerns Thüringer Waid Verarbeitungs GmbH (TWV) about the “Development of environmentally and health-friendly paints for the protection of wood and buildings on the basis of woad (Isatis tinctoria L.)”, which was basically about the presentation of the work steps and the applied methods, optimisation of the technology in woad processing with improved process design and control - in particular fermentation and product manufacture of wood impregnation and paints. *(Feige, 1999)* The second part was prepared by the Thüringer Landesanstalt für Landwirtschaft Jena-Dornburg (TLL) about the “Provision of improved plant material for effective woad cultivation and processing in Thuringia by selection of woad origins”, which concerns the selection of woad strains that ensure a significant increase in efficiency in agriculture while maintaining the effective systems. Processing costs should be reduced with optimal raw material properties. *(Vetter, Foltys de Garcia, 1999)* The third part was carried out by the Hans Knöll Institute for Drug Research in Jena (HKI). “Biotechnological, chemical-analytical, mycological and toxicological investigation for process optimisation and validation of paints based on woad”. This part is about the continuous quality assurance and evaluation of the product ingredients through accompanying biotechnological and toxicological investigations and their validation. *(Hilliger, et al., 1999)*

The result and conclusion of this project: through the cooperation of all three project partners, workflows from cultivation to first processing of the plants to the production of impregnation and paints were determined and defined, including the quality control accompanying production and with the technology developed here. Standards for the production of market-driven, toxicologically harmless and environmentally friendly wood impregnation and wood paints have been developed.

The core of the DBU project was to find out under which conditions which woad plant produces the best yield with regard to the desired substances and ingredients. At the HKI, research was carried out on four different levels, biotechnological, chemical-analytical, mycological and toxicological, in very different ways. For example, what chemical substances were found within the different woad substances and how they were assessed, particularly with regard to toxicity. The collaborative character of this project is particularly important as it has been investigated how process optimisation and validation of the TWV can be supported. With the help of the combination of university and non-university research, the hope of the project was to find additionally

preparations for medical application based on the research on glazes and dyes. *(Interview with Professor Axel Stelzner, Director of the Institute of Virology at the University of Jena and head of a working group at the HKI from Langanki et. al. 1996.)* Even though this project was organised with these three promising partners, the project did not develop into a successful business. Official reasons for the difficulties include the financing of the project and the burglary into the office of the TWF, which is mentioned in more detail in the analysis of the interviews chapter.

From 1992 until 1997, the Deutsches Zentrum für Handwerk und Denkmalpflege in Fulda ZHD (Centre for Crafts and Monument Conservation) has worked on a small research project to investigate the weathering behaviour of wood and timber frameworks treated with woad paint in comparison to other commercially available products. For this purpose, a long-term investigation of various test timbers of different ages was carried out on weathering stands, which were set up on the premises of the ZHD building yard and then continuously observed and investigated for 4 years. A total of 18 specimens were prepared for testing, two of which were completely identical. One was coated with woad products and the other with other commercially available wood preservatives, from which a direct comparison was made during continuous observation. In summary, it can be stated that woad paint is a coating system suitable for weathered woods, but that in comparison to dispersion paints there was no one-sided evaluation in favour of one or the other product. The weathering behaviour was primarily dependent on the substrate. Depending on the type of wood (oak, spruce, pine, larch), surface treatment, quality and moisture (age) of the test woods, the results for the two coating systems differed, sometimes significantly, sometimes minimally. *(Ney et al., 1997)*

MEDICINE AND COSMETICS

The origins of domestic medicinal plant production go back to medieval monastic medicine. Today, the pharmaceutical industry is interested in the traditional principles of action. Currently, 75 indigenous species are cultivated on around 12,000 hectares in Germany. Preferred regions are Thuringia, Bavaria, Saxony and Saxony-Anhalt as well as East Frisia in Lower Saxony. However, domestic cultivation represents only one niche: 90 percent of the processed medicinal plants are imported. In addition to their use in medicine, medicinal plants for cosmetics and food supplements are gaining importance. *(Pflanzen für Industrie und Energie, 2019)*

A lot of in vivo and in vitro studies have been conducted, which reveal the anti-inflammatory and anti-cancer assets of lipophilic extracts and isolated compounds from Isatis tinctoria. The beneficial health effects of various alkaloids involving tryptanthrin, indirubin and indolinone have been extensively examined. *(Ronald Steriti, 2002)*; *(Eisenbrand et al., 2004)*; *(Recio et al. 2006a, 2006b)* In the traditional Chinese medicine Isatis tinctoria and its interrelated species Isatis indigotica are currently applied. *(Condurso et al. 2006)* Traditionally, Isatis tinctoria has been used for the treatment of wounds, ulcers and tumours, haemorrhoids, snake bites and different inflammatory conditions. *(Hamburger, 2002)*

All the research that has been conducted about woad in terms of conventional medicine could not be implemented in the market as a drug of academic medicine. Professor Dr. sc. nat. Matthias Hamburger from the university of Basel has studied Isatis tinctoria very intensively in order to systematically and exemplarily show how a de novo development could be realised in today's methodological possibilities until the point of product development. The results are approximately 25 publications and several patent applications. On the one hand the entire phytochemistry was researched, characterising the extract in detail, comparing studies on the cultivation level on the origins and seasonal changes of the ingredient patterns. On the other hand, the pharmacology was researched by in vitro characterisation of the active ingredients as well as animal pharmacology. Even a clinical pilot study in dermatological application was carried out. The problem are the costs involved to market a project like this. The extract would be a "New Herbal Entity", which leads to expensive investigations of around 2 million euros for the regulatory toxicology. *(Meier et al., 2012)* Up to now, no company was willing to take on the risk of doing the regulatory toxicology. Since the drug regulatory affairs are not only justified by the regulatory toxicology, but there would also be further expensive regulatory requirements (clinical studies), which would be very cost intensive until the drug would be allowed on the market. *(M. Hamburger, personal communication, October 10, 2019)* One of the big problems is that the pharmaceutical environment is rather retrograde and rigid, which is ultimately anti-innovative. In addition to classical phytotherapy, natural substances are increasingly being investigated in the food sector. The functional foods and cosmetics sectors are more innovation-friendly, because the regulatory environment is less rigid in these areas. *(Meier et al., 2012)*

Woad offers a further application possibility in cosmetics, since the oil-containing or alcoholic-aqueous extract of the plant has a favourable dermatological and caring effect. Since 1992, the Nuth GmbH & Co. KG (a company in Thuringia) has been researching and developing cosmetic products from extracts of the Thuringian woad plant to manufacture cleansing, vitalising and care products. For the time being, the cosmetic preparations range from a day cream, night cream, facial tonic, cleansing balm, care lotion, body lotion, shampoo to foam bathing products. The cosmetic series made of woad products is an environmentally friendly product range and promises clean care for every skin type. *(Nuth Chemie – Pflegeprodukte, 2019)* Waidea or neurodermitis skin care with biological woad focuses on solutions for skin problems. The effect of the old medicinal plant woad plays a central role. The work was triggered by skin diseases within the family, friends and acquaintances. The founder of the company has experience in that field due to his work as the head of a well-known German brine spa, which is especially visited by people with skin and respiratory diseases. Although the company is convinced that there is no patent recipe to cure or alleviate skin diseases, various approaches can help those affected. One approach is the woad plant with its strong anti-inflammatory properties. The products of Waidea skin care series consists of the following products: facial cream, hand cream, foot cream, shower bath, shampoo and body lotion. *(Neurodermitiskosmetik, 2017)* A decisive difference in the designation "organic" in food does not necessarily have to be organic in the case of organic care and cosmetic products, since there is no legal provision defining the term. In order to be allowed to call oneself "organic", cosmetic products do not first have to be certified by inspection bodies. The final certainty that organic cosmetics contain a high proportion of organically produced products will, however, only come with a binding, legal seal, which does not yet exist. *(Utopia Team, 2019)*

The company Dermasence was founded in 1991 by an initiative of five dermatologists and one pharmacist. They wanted to develop formulations for skin care products with the guiding principle of a consistent focus on effectiveness and compatibility. In the meantime, Dermasence has established itself on the pharmacy cosmetics market with over 50 products. With the Medicos Science Center GmbH based in Bernburg, Dermasence has its own competence centre for the cultivation and processing of herbal ingredients**.** Two Dermasense products use the anti-inflammatory and anti**-**

irritant effect of woad: Vitop forte, an intensive care cream for neurodermatitis and Barrio Pro cleansing foam, an anti-irritant cleansing foam. *(Dermasence, 2019)*

In China, the woad (Isatis indigotica) plays an important role in TCM as a medicinal plant. Isatis indigotica is related to Isatis tinctoria and used in traditional Chinese medicine. The names sometimes cause inaccuracy, because some botanists regard this name as a synonym for Isatis tinctoria. In autumn, the roots are harvested and the dried root is pressed into granules, which are mostly dissolved in heated water or tea. The root (banlangen) is used against fever ("heat in the blood") and feverish infections in the throat and throat area, e.g. angina, tonsillitis or flu. The daily dose is 9 to 15 grams*. (Yi et. al., 2014)* In 2013, many locals tried to protect themselves against the bird flu virus H7N9, which occurred in eastern China. The roots of woad were sold out in many TCM pharmacies in Shanghai and the provinces of Jiangsu, Zhejiang and Anhui. Although the postulated effects of the woad root are not supported by experimental studies, the Health Department of Jiangsu Province recommended its use against the H7N9 virus, especially as synthetic virustatics are not very effective. *(Caesar, 2013)* An interesting evolvement in China is the new wave of European patent applications for Isatis tinctoria. Experts assume that the intellectual property operations fund is a kick-start for a developing knowledgeable economy, in terms of providing financial "wings" for intellectual property and will introduce new developments of intellectual property. Two funds, mutually financed by both the Chinese central and local governments, will focus on the intellectual property of current essential technologies and patents of leading technology with industry forecasts for the near future. The first stage of investment by Beijing Key Industry IP Operations Fund will emphasise on other areas of the bio-pharmaceutical industries. Sichuan IP operations Fund will, for instance, invest in IP operation enterprises with strong IPR, cultivation and operations of high-value patent portfolio. *(Ccpit Patent and Trademark Law Office, 2016)* For Isatis tinctoria there are some patents applications from Chinese people in the European patent office for instance: Isatis tinctoria planting method, Isatis tinctoria forestland planting method, technology for treating Isatis tinctoria, special pre-emerge herbicide for Isatis tinctoria, method for preparing Isatis tinctoria honey tea, Isatis tinctoria-containing sheep feed additive preparation method as well as a centrifugal screening equipment for Isatis tinctoria and more. *(Isatis tinctoria – TIB, 2019)*

NATURAL PLANT PROTECTION

From 1991 until 1994 the Federal Ministry of Agriculture (Bundesministerium für Landwirtschaft) was conducting a research project about "Screening of dye-supplying plants". *(Kaiser-Alexnat, 1994)* For this research project Renate Kaiser-Alexnat was delegated with the cultivation and evaluation of a range of dyeing plants at the Federal Institute for Breeding Research on Cultivated Plants (Bundesanstalt für Züchtungsforschung an Kulturpflanzen, BAZ) at the Institute for vine breeding Geilweilerhof (Institut für Rebenzüchtung Geilweilerhof), now part of the Julius Kühn Institute. In the selection of suitable dyeing plants, the woad plant was taken into special consideration for local cultivation. In addition to the cultivation of an extensive range of dye-supplying plant species with a broad spectrum of origin, literature studies and discussions with representatives of the processing industry were carried out. The 62 origins of the woad in the range were cultivated on the experimental field and showed a very high variability. The project results were presented at the 6th Thuringian Waidtagung in Pferdingsleben and published in the corresponding proceedings. *(Beiträge zur 6. Thüringer Waidtagung in Pferdingsleben, 1994); (Kaiser, 1993)* Further research projects were carried out at the Federal Biological Institute for Agriculture and Forestry (BBA) in the Institute for Biological Plant Protection in Darmstadt, today also part of the Julius Kühn Institute. The research possibilities in the field of "renewable raw materials" were examined in the course of the subsequent research by Renate Kaiser-Alexnat in 2006/2007. The aim of this study was to find out how much of the woad plant is used and how strong the inhibitory effect of weed control is on the germination and young plant development of selected weeds. For example, field thistle, sorrel and couch grass as well as weed seeds contained in the soil. As a conclusion, Renate Kaiser Alexnat stated that the germ inhibiting effect is present, but with the applied form of application, i.e. the introduction of decomposed woad fruits into the soil, the yield rates are too high for the field conditions. *(Kaiser Alexnat, 2014)* In the scenario of a change in the processing of decomposed woad fruits and their application, it is conceivable that the allelopathic effect would be of interest for certain applications such as biological plant protection. *(Kaiser-Alexnat, 2014)* In the last decades further ingredients could be isolated in the woad leaves, e.g. Indirubin, Indigbraun, Tryptophan, Isatin, Isatan, Sinapin, Querecetin, Kaempferol and Stachyose. *(Seifert, 1989)* These numerous ingredients potentially offer many more applications still to be investigated. However, for publication in the newsletter of the German Plant Protection Service, it

must be made clear that the study is based on pot experiments carried out to a small extent in greenhouses in order to confirm the germ-inhibiting effect of woad pods with very high application rates. This may be a basis for a larger research project, whereby the approach has so far been expensive and therefore uneconomical, as very large quantities are required for soil application in order to achieve the germicidal effect proven in pots under greenhouse conditions. At the Institute for Biological Plant Protection, laboratory tests were also carried out on the effect of fresh and fermented woad leaf juice on various pests and plant diseases and were listed and published at the "7th Waidtagung in Pferdingsleben". In the aforementioned preliminary experiments, the effectiveness of leaf extracts of the woad could only be proven in seed-born fungi of the carrot (Alternaria radicina, Alternaria dauci). *(Kaiser-Alexnat, 2013)*

Further research has been completed to differentiate whether the germicidal effect is due to the seeds or the pods, i.e. the fruit tissue. In the course of this study, the glucosinolate contents in the corresponding plant parts were investigated in 2010 in collaboration with Dr. Wolfgang Schütze from the Julius Kühn Institute. *(Kaiser-Alexnat, 2013)* The results were presented at the 7th Waidtagung in Pferdingsleben and additional details are accessible in a table in the corresponding proceedings. The glucosiolate content in the pods was very low (2 µmol/g TS) and very high (154 µmol/g TS). Their high concentration, i.e. the formation of isothiocyanates after myrosinase cleavage (ITC, mustard oils; only sinigrin, progoitrin does not form ITC) probably leads to germ inhibition. *(Personal communication, Dr. Wolfgang Schütze, 2010)*; *(Kaiser-Alexnat, 2013)*

FIGURE 2: HERBICIDAL ACTION OF WOAD PODS ON A SUGAR LOAF SPRUCE

Kaiser-Alexnat R. (2015, 13. September): Dyeplants.de. Retrieved 10 November 2019, from http://www.dyeplants.de/images/popup/WaidBioHerbizid.jpg

FOOD SUPPLEMENT FOR HUMANS AND ANIMAL NUTRITION

The study in Sicily about the phenolic profile, antioxidant and cytotoxic properties of polar extracts from leaves and flowers of I. tinctoria growing wild around Acireale (Sicily, Italy)" *(Taviano et. al., 2018)* confirms that the polar extracts from leaves and flowers are a possible source of antioxidants coupled with anti-cancer drugs which may be applicable for nutraceutical and therapeutic purposes. Furthermore, the research project established the relationship amid the effects and presence of phenolic composites. Woad is an evident source of indolic compounds, bioactive molecules useable as fine chemicals, like glucobrassicin and its derivatives, which appear to be antitumoral. Considering that differing Brassicaceae (for example broccoli and cauliflower) include glucobrassicin, an investigation about the metabolic system after the outcome of the pure compound in vivo. *(Galletti et.al., 2006)* But currently, the research is halted by the complications of purification, mostly as a result of the lack of a rich plant source and the complications and expenses involved with synthetic

production. In the 2006 report: “Glucobrassicin enhancement in woad (Isatis tinctoria) leaves by chemical and physical treatments”, the aim was to investigate the probability of improving glucobrassicin in woad leaves as a result of artificial wounds and fertilisation, in both the field and greenhouse, to gather a high content for an appropriate purification of the compound. Jasmonic acid treatment on juvenile woad leaves from the accession of Casolavalsenio has been shown to be very effective in improving glucobrassicin content under greenhouse conditions, particularly combined with N-S fertilisation. The use of jasmonate acid would be for wide-ranging outdoor assembly too cost intensive. Another stimulation method could be artificial wounds, capable of causing an astonishing rise in the compound. This results in above 1% d.w., permitting its purification. *(Galletti et.al., 2006)* Stefania Galletti and her Italian team from the University of Bologna hope their results will facilitate the conduct of such studies. They discovered that woad comprises twenty times the amount of glucobrassicin than in broccoli. By damaging the leaves of the plant, more glucobrassicin could be released from the plant as a defense mechanism, thus increasing its concentration. Glucobrassicin was found to contain anti-tumor characteristics, which are especially effective against mammary cancer. Investigators have thus far proposed that consuming vegetables containing multiple chemicals such as glucobrassicin could aid in the protection of people against cancer. Findings propose that glucobrassicin eradicates carcinogenic composites, including estrogen derivatives. "The availability of glucobrassicin in good quantities and at low cost could finally make it possible to conduct studies to clarify the cancer-fighting role of glucobrassicin-rich vegetables, such as broccoli, in human nutrition," Stefania Galletti told the Journal of the Science of Food and Agriculture. *(Galletti et.al., 2006)* In 2006 Kat Arney, the information officer at Cancer Research UK, said: "The natural world is a rich source of molecules that can benefit human health. This new way of growing woad, a plant from the same family as cauliflower, could allow researchers to get hold of larger quantities of potential anti-cancer agents. These can then be tested further in the lab and in patients. Chemicals like these could one day prove to have an important part to play in the prevention and treatment of cancer." *(Hall, 2006)*

Based on the study from Galletti et al. in 2006 in 2008 a study has been conducted from the Institute of Animal Nutrition (Institut für Tierernährung), Friedrich-Loeffer-Institut (FLI) and the Federal Research Institute for Animal Health (Bundesforschungsinstitut für Tiergesundheit) on the influence of woad (Isatis tinctoria)

and ginkgo (Ginkgo biloba) on growth of broiler chickens. This study from 2008 based on the research of woad, assuming the plant could possibly be useful in preventing cancer because compared to broccoli, known for its high content of glucobrassicin, woad contains twenty times the amount. (Galletti et.al., 2006) The intention of the research study was to identify the outcomes of a diet supplement with woad or ginkgo on broiler performance. (Halle, et al., 2008) Woad and ginkgo increased the daily feed intake of broiler chickens. Compared to the control, the daily weight gain of the animals in woad groups and ginkgo groups between 21 and 35 days of age and also over the 35-day growing period was significantly higher, when all treatment groups were combined and tested against this control. Feed conversion was not significantly improved. No effects on the carcass quality of chickens for fattening could be demonstrated. The study demonstrates that the most pronounced effect of woad and ginkgo supplementation was increased feed intake and final body weight. In further trials the mode of action has to be cleared. The study was not carried out over a longer period and there is only very few research information about this study. Also, from the study of Galletti et. al. no further products or outcome could be introduced to the market from the results of this project.

5 RESEARCH DESIGN AND METHODOLOGY

In this thesis the methods used to undertake the research was the qualitative research method. The research design and methodology chapter clarify the methods used to assess the dependability and legitimacy of this study. Included are the kinds of investigation and the model, in what way the data was gathered and analysed. Furthermore, the tools and materials for this research methodology are explained as well as the rationale for choosing these specific methods.

5.1 QUALITATIVE RESEARCH METHOD

“The definition of qualitative research as a market research method concentrates on attaining data through open-ended and conversational communication. Therefore, in qualitative research methods the investigator also attempts to comprehend incentives and emotions of the interview participants to enable in-depth and additional probing and questioning of respondents. For market research, knowing how your target market makes decisions can assist in developing conclusions.” *(Bath, 2018)*

Qualitative research was used as a research method because for the exploration of the business ideas, there is not sufficient literature. For gathering information for the research questions, the qualitative research method was the most appropriate to find information, because the in-depth questioning and communication makes it possible to obtain data for the research objectives. For the complexity of the exploration of business ideas for the woad plant, less literature is available, and the qualitative research is essential to make the subtlety research more manageable. For understanding the context and environment of the woad plant and its possible business ideas it is important to have contact to experts to observe and collect the data. The qualitative method enables the researcher to get detailed explanations for specific questions. *(Creswell, Poth, 2017)* Only people with an in-depth knowledge are able to answer these kinds of questions. For the exploration of business ideas of woad qualitative research methods offer the best possibilities for collecting the data. The reason for this is that qualitative methods, in this thesis with one-on-one expert interviews, help to define, interpret, putting into context, and to comprehend in-depth insight into a precise theory.

Literature about possible applications of the woad plant for products hardly exist and therefore the pure implementation for business ideas from existing literature did not guarantee a profound research outcome. Therefore, this research project is an inductive as well as deductive theory, which aims to test if there are business ideas about the woad plant. The hypothesis, “business ideas of the woad plant exist” and “the exploration of business ideas of the woad plant is possible”, were underlined and supported by the research objectives. On the one hand the theoretical framework revealed preconceived ideas and themes, on the other hand the framework was developed and based on the findings.

5.2 CASE STUDY MODEL

“A case study model is able to be defined as an in-depth investigation of a specific situation instead of a far-reaching statistical survey. This technique is utilised to limit an extensive field of research into a single researchable topic. Although the approach does not fully answer a question, it will provide indications and permit supplementary elaboration and hypothesis formation on a topic.” *(Shuttleworth, 2008)*

TABLE 4: SEQUENCE OF A CASE STUDY METHOD

Research Questions: how, why, where, what?
Unit of analysis (individual, group or organisation)
Linking the data
Interpretation of findings

Sequence of a case study method (Yin 1994) Yin, R. K. (1994). In Case study research: design and methods (p. 2).

For this thesis the case study model was chosen, because it provides an in-depth look at one test subject. In this case the subject is the woad plant. For a comprehensive conclusion the data is obtained from different sources and summarised with the details. For marketing, to new customers case studies are often chosen by businesses to show how their business solutions solve a problem for the issue. *(Cross, 2017)*

The study case provides insights into the exploration of business ideas in different areas of the woad plant. Existing literature does in some areas like medicine go into

detail about the different features of woad. However, this case study goes more into detail which specific applications of woad, which could have a chance on the market. The case study model was chosen as a research design, because it allows the researcher to gain particular, contextual, profound expert knowledge to explore the implications and key characteristics of this case The case study implicates the traditional uses of woad as an ecological building material, and how woad can be used for other functions. Furthermore, the competitive advantage of woad in the market is analysed.

The project is expanding the existing literature theories about the applications of woad in the areas of building materials, medicine and cosmetic, biological pesticide and herbicide, insulting material, dye plant for textiles and art of painting, food as well as animal nutrition. It challenges a lot of theories of the woad plant in which only very less literature exists, like the application as food or animal nutrition. Otherwise, the problems in the market for medication, cosmetics and building materials are investigated to show how in the literature the practical implementation is often not taken into detailed consideration.

The data was mainly collected through expert interviews. Eight woad experts have been interviewed one-on-one with a semi-structure and follow-up questions to enable the researcher to gain a comprehensive understanding of the case and its context. In addition, there has been personal communication with expert of historical preservation to investigate about the research of woad as a building material for renovation work.

This case study has also been carried out to open up new directions for future research about possible business positions and strategies of the woad plant. Also, the detailed interviews of the woad experts about business ideas are a literary source for further research about the possible applications or business plans with woad.

5.3 DATA COLLECTION TECHNIQUE

For the data collection eight individual one-on-one interviews with woad experts were conducted. In order to gain a better insight into the exploration of business ideas of the woad plant, semi-structured in-depth interviews were conducted with eight woad experts from different business areas and research background. Interviews were

conducted at the place chosen by the participant and lasted approximately 60 minutes. Answers were audio-recorded, and notes were taken during the interviews.

The participants for this research project were mostly found by the researcher through literature about Isatis tinctoria conducted by the participant or knowledge about the woad plant through business and own interest. Also, some of the interview participants have been suggested by previous interviewees. The woad experts have been selected due to their publications and research in the areas of medicine, building materials, pesticidal use of woad, and more topics concerning possible woad applications. The literature needed to be applicable for further interview questions about business ideas. Another factor important for the selection of the experts was their current permanent address, since almost all interviewees have been interviewed in person by the researcher.

In total eight people took part in the research project as woad experts. Seven persons from Germany and one person from Switzerland have been interviewed with the same semi-structured interview with six questions. Additionally, three more people have been asked questions about woad by personal communication.

In a qualitative ethnographic case study, the goal is to generate related actual information about the behaviours, social constructions and shared principles of a particular cluster of people. As this methodology is less structured and more interpretative, it is essential to examine on the position as an investigator, considering how your contribution and viewpoint might have effected the results. *(Mohajan, 2018)*

The interviewer conducts a personal in-depth interview with one respondent at a time. The one-on-one interviews are conversational and include open-ended, unstructured questions. *(Bath, 2018)* It is a valuable chance to gain a profounder insight of a participant's view with regards to goods, services or corporations, because the interviewee has the freedom to express himself. *("4 Types of Research". 2019)* An advantage of interviews is that if the investigator is questioning using the correct questions, he is able to gather insightful information. For getting more data the investigator can request for further questions, which can aid in the collection of additional data.

The interviews took in the medium around 60 minutes. The interviews were semi-structured and due to open ended answers, some of the interviews have a length of

30 to 90 minutes. For ensuring the interview contributors were able to reply using their individual expressions and more involved than “yes” or “no”, the questions were open-ended. The interviews were audio-recorded by a device and transcribed by the investigator. The full interviews are not included in the thesis just parts of it to the suitable topic.

Most of the interviews were executed face-to-face and some on phone. Regularly one interview lasted between half an hour and one hour. When the in-depth interview took place face to face, the connection to the respondent was better and there was the chance to observe the body language and match the responses. *(Bath, 2018)* There is also a risk of an interview that allows you to request for follow-up questions. If the interviewer is probing important questions that do not reflect the point of view of the interviewee the actual point of view to a topic can be biased. *(“4 Types of Research”. 2019)*

5.4 SAMPLING PROCEDURE AND TECHNIQUES

The data was collected by a non-probability sampling method. The non-probability sampling is the types of research to acquire a primary understanding of a minor and specific group of individuals.

Specifically, the type of purposive sampling was used in this thesis to guarantee the most useful sample for the research objectives. Purposive sampling is a typical technique for qualitative research, where the investigator wants to obtain comprehensive information about a specific phenomenon rather than creating statistical implications. An effective purposive sample requires precise criteria and justification for insertion. *(Sampling Methods | Types and Techniques Explained, 2019)*

The criteria for the sample in general was a profound knowledge about the woad plant. Some of the eight participants have published literature about a specific research topic concerning the woad plant. All of them have researched about the woad plant and some have gained their insight knowledge due to their profession at universities, in the pharmaceutical industry, as farmer, master painter/craftsman or restorer and a lot of experience as textile dyer with woad.

Also, the snowball sampling was used to recruit more participants for the interviews. The already interviewed participants have been asked for other possible participants, because the experts in this field know each other and can recommend themselves.

5.5 DATA ANALYSIS TOOLS

Qualitative data is a collection of data acquired from interviews, fieldnotes of observations and analysis of documents. For the research work this data has to be organised, structured and interpreted properly to explore the key findings. The research analysis starts with a large body of knowledge and information. Inductive reasoning, sorting and categorisation must be utilised. *(Creswell, Poth, 2017)*

Analysing the interviews is repeatedly a more supple procedure that includes the researcher's subjective analysis. The focus of the data analysis was on recognising and classifying key topics, understanding patterns and descriptions, or understanding social context and meaning. *(How do you incorporate an interview into a dissertation?, 2014)*

During the analysis of the interviews only the participants' perceptions and experiences were relevant, not the emotions or the social context. Therefore, the analysis was focusing only on what was said by the interviewee.

The intelligent verbatim transcription was used as a transcription method. Even though, some data like pauses hesitation and emotions get lost in the process, this method was chosen, because it improves the readability and leaves out irrelevant phrases.

The interviews were transcribed, and the analysis of themes was conducted. This included coding all of the information prior to classifying and evaluating six key themes. Each theme was observed to develop an understanding of contributors views and incentives.

Thematic Analysis (TA) is a flexible method of qualitative data analysis. This method of analysing the conducted interviews with the woad experts provided the qualitative investigator with a basis of the basic skills required to engage with additional methods to qualitative data analysis*. (Braun, Clarke, 2012)* It is a six-step method for analysing the data developed by Braun and Clarke.

Familiarization: For this step the researcher was getting a deeper overview of all the data collected before he is analysing the individual topics. The audio-recorded data was transcribed and after that the researcher got familiar with all the collected data to get the first impression of the outcome.

Coding and generating themes: The first and most important for coding and generating themes was done by the six different applications areas and business ideas of the woad plant. The interviews were all separated into six main themes about the most important applications of the woad plant. After the separation into these six areas the next codes in the interviews were prepared with noting down the most relevant and interesting answers of these different applications of each interview participant. Furthermore, the interviews were coded for similarities of the participants answers. When answers were with all the participants quite similar for a specific question the differences were highlighted.

Reviewing themes: The themes and codes have been reviewed to make sure the data set is not missing something and to compare the themes against each other. In the end a precise and valuable representation of the interviews was ensured by the reviewing.

Defining and naming themes: For this step the data with the different themes was defined and named to understand and formulate the exact meaning of each theme.

Writing up: For the analysis of the interviews the data was divided into the six main themes which are the six interview questions about the different applications of the woad plant. Additionally, the results and findings of each theme and code of the dissimilar main theme was analysed in this last step.

5.5.1 INTERVIEW QUESTIONS

1. Which application of woad as an ecological building material (facade painting, wood impregnation and sandstone sealing) would have the greatest chances in the market and why?
2. What are the chances, considering woad can be used as a textile dye, in the textile market?
3. Why could the application of the plant woad have a future in medicine and cosmetics?

4. Could woad be usable as a whole plant, e.g. for biogas or as an ecological insulating material?
5. Does woad have a chance in agriculture as a biological pesticide or biological herbicide?
6. In which market is the competitive advantage of woad for you the most prominent?

5.6 JUSTIFICATION OF METHODOLOGICAL CHOICES

The rationale for choosing these methods was the fact that there is not a lot of literature available to respond to the research objectives of this research project. Moreover, the topic is very specific and only a few experts have the knowledge to contribute for this research. Therefore, qualitative research with an inductive as well as deductive approach with the hypothesis that there are business ideas of the woad plant was the chosen method. The case study model was chosen because it is a method, which allows to narrow down the research into one straightforwardly researchable topic, while indications and further elaboration is possible. A purposive sampling to find woad experts for semi-structured in-depth interviews and a thematical analysis of the interviews was chosen, because the research questions need specific people, who have the freedom in the interviews to answer as long as they want to get the best outcome of the research. Encountered difficulties in collecting or analysing data, was for example, that some experts interviewed were only experts in a specific application area for the woad plant. In this case the answers of the experts were often very short stating they did not have scientific knowledge about the topic. But in general, they could answer every question in detail. The research project had to be approached as rigorous as possible, because the semi-structured interviews also produced results, that could hardly be generalised beyond for the whole sample group. Besides this effect, the participants' perceptions, motivations and emotions were turned out with a semi-structured interview, which is a method that provides a more in-depth understanding of the research.

5.7 ETHICAL CONSIDERATIONS

The ethical and political considerations are essential, when writing a master thesis and there are certain consideration and rules, that have been followed in this research project. In terms of the research project design, it must be considered, that the

investigator is marginally experienced in conducting research projects. The accessibility purposive selection has been used to contact participants. In this context the method was also utilised to protect the rights of the contributors. Concerning the intellectual liberty, the researcher process and all its results are owned by the investigator. The investigator is aware of the ethical challenges in all stages of the study and will protect the rights of the contributors. For the data collection through interviews informed consent from the participants was achieved by obtaining written consent. Participants understood they took part in research and consented to it. When analysing the data, it was interpreted solely by the researcher. For the report of the discoveries all stakeholders, researcher, supervisor and participants, have admission to the information and results. The chosen subject is not controversial, politically as well as religiously focused and is not exploring a sensitive issue with an individual, consequently it is unlikely to be censored. *(Minichiello et al. 1995 and Flick 2015)*

5.8 SCOPE AND LIMITATIONS

The construction of research aims, and research objectives might have been expressed too broadly and therefore a more detailed formulation is required, for increasing the level of focus of the research project. In terms of the implementation of data collection method the researcher has no wide-ranging experience in primary data collection. There is a deficiency of previous studies in the investigation area. Nevertheless, the literature review is an essential part of the research, because it helps to identify the scope of works that have been done so far with the woad plant. Literature review discoveries are the basis to be built upon to attain the research objectives. Concerning the scope of discussions, the research was limited because, there are not a lot of references concerning the future of a product out of woad or business ideas and further possible applications. In some areas like medicine a lot of literature is available. Furthermore, the references show, that there is a lot of literature about the history of woad, but only an insufficient amount about its potential applications. *(Research Limitations - Research-Methodology, 2018)*

6 EMPIRICAL MATERIAL

6.1 PARTICIPANTS PROFILES AND THEIR CONNECTION TO WOAD

FIGURE 3: RENATE KAISER-ALEXNAT

Within the scope of a research project of the Federal Ministry of Agriculture (Bundesministerium für Landwirtschaft) on the topic "Screening of dye-supplying plants", from 1991 to 1994, Renate Kaiser-Alexnat was entrusted with the cultivation and evaluation of a range of dyeing plants at the Federal Institute for Breeding Research on Cultivated Plants (Bundesanstalt für Züchtungsforschung an Kulturpflanzen, BAZ) at the Institute for vine breeding Geilweilerhof (Institut für Rebenzüchtung Geilweilerhof) in the Südpfalz, now part of the Julius Kühn Institute. The aim of the research project was to select from the large number of native dyeing plant species those which are suitable for cultivation under local cultivation conditions today. In order to arrive at a meaningful selection, literature studies and discussions with representatives of the processing industry were carried out in addition to the cultivation of an extensive range of dye-supplying plant species with a broad spectrum of origins. The woad - as one of the most important Central European dyeing plants - was given special consideration in the project. The 62 origins of the woad in the assortment were cultivated on the experimental field and showed a very high variability. The project results were presented at the 6th Thuringian woad conference (Thüringer Waidtagung) in Pferdingsleben and published in the corresponding proceedings. *(Beiträge zur 6. Thüringer Waidtagung in Pferdingsleben, 1994)*

Many years later Renate Kaiser-Alexnat engaged in other research tasks at the Federal Biological Institute for Agriculture and Forestry (BBA) in the Institute for Biological Plant Protection in Darmstadt (Institut für Biologischen Pflanzenschutz), today also part of the Julius Kühn Institute. At a meeting of the institute council, the head of the institute encouraged her to examine the research possibilities in the field of "renewable raw materials". She immediately remembered the dye plants and her former enthusiasm was revived at the same moment. In the course of the research

that followed, Renate Kaiser-Alexnat's attention was drawn to the woad in 2006/2007 because it has characteristics in which she saw a potential for biological plant protection due to the wood preservative developed by Wolfgang Feige. Since since 2009 Renate Kaiser-Alexnat is working in Bonn as research promotion officer at the Federal Agency for Agriculture and Food. *(Personal communication, September 24, 2019)* Renate Kaiser-Alexnat initially wanted to found an "Institute for Dyer's woad" in order to continue her enthusiasm for the woad plant in a different way. Finally, she created the private homepage "Institute for dye plants" under the domain dyeplants.de, a platform for all dyeing plants and natural dyestuffs. Although the homepage is an information platform for all dyeing plants, the woad is especially considered as "leading plant", which is optically expressed by the fact that the warm woad blue was chosen as background colour and the logo is based on a drawing of the woad, additionally, all literature references and new information about the woad are updated very precisely.

FIGURE 4: SUSANNE FRENZEL

Since April 2019 Susanne Frenzel from the Ökotrend Projekt und Marketing GmbH is building a network from for dyers plants like woad, reseda and madder. The aim of the project is to build a network of actors for the preservation and use of the potentials of versatile useful plants especially woad. Susanne Frenzel grew up in Berlin and studied art at the University of the Arts, but never encountered natural plant colours during her studies. Later, she had dyeing plants in her mind when working on a project sketch in Thuringia in Auerstedt, where an environmental education centre was to be set up to support the rainforest in Brazil. The plan was to build a Maloca in Auerstedt, a house for teaching and learning in order to pass on the traditions that have their origin in the indigenous people of Brazil. Susanne Frenzel wanted to combine the Maloca project with setting up a dye garden. In this context, she has dealt with various dyeing plants, which could then be taken up in the garden. By moving from Berlin to Erfurt, where the dyer plant Waid is unmissable, she became more familiar with the most famous blue dyer plant from Thuringia. Unfortunately, the environmental education project was not

realised and has now developed into a location for weddings. Later she started an environmental education project in a Waldorf school, where the pupils were taught the relation to dye plants. For the elementary school pupils, this topic fit into the local history and for the higher levels into the chemistry lessons. In the chemistry lessons also other dyeing plants like madder and goldenrod were extracted. The woad, which only oxidizes in the air and slowly turns blue, illustrates a redox reaction in an exciting way. *(Personal communication, September 25, 2019)*

FIGURE 5: ANDREA BIERTÜMPFEL

Dipl.-Ing. agr. Andrea Biertümpfel is working for the TLLLR and published a cultivation guideline for the woad plant. She also researched about the dying ingredients of Isatis tinctoria in comparison to other plants with the Fachagentur Nachwachsende Rohstoffe e.V. (Agency for Renewable Resources). In the 1980/1990s, master painter Wolfgang Feige dealt extensively with the Thuringian woad and during this time the Thuringian State Institute for Agriculture (Thüringer Landesanstalt für Landwirtschaft) was founded as well as the department "Renewable Resources". In this context we became attentive to Wolfgang Feige and thus also to the woad. The guideline of the Thuringian state institute for agriculture for woad came many years later, after we have occupied ourselves with dyeing plants and also with the woad. The guideline of the cultivation of woad was brought to life by the question of the forgotten plants, how to cultivate them and how to cultivate the mother plants. The guideline was finally drawn up on the basis of our knowledge of colouring agents, fungicidal ingredients and other active substances. *(Personal communication, September 23, 2019)*

FIGURE 6: WOLFGANG FEIGE

Wolfgang Feige is famous for his woad research and won a lot of prices for his research and the manufactured products using the woad plant. He was in eastern Germany a master painter and rediscovered the woad plant in the emblem of his hometown Neudietendorf. In the 1980 contact was established with farmers from an LPG in Apfelstädt, which cultivated half a hectare of woad. This development also led to contact with the agricultural cooperative and the Dornburg Breeding Research Department of the Quedlinburg Institute for Breeding Research of the Academy of Agricultural Sciences (approx. 1982). Later Dornburg research institute as part of the LUFA Thuringia or Thüringer Landesanstalt für Landwirtschaft (TLL) with headquarters in Jena. Since then, the Experimental Station/Department of Breeding Research in Dornburg has been a constant companion for woad research. Later, Mr. Wolfgang Friebel cultivated one hectare of woad in Kornhochheim for seed propagation. There was a constant exchange between science and practice, politics played no role. The project was expanded in a mill in Neudietendorf. Since then, the government has been interested in woad and hired Wolfgang Feige for a woad project in the Bitterfeld combine. The project was passed on to the highest political authority, which meant that the State Security Service (Stasi) was always present. After his referral to the Kombinat Bitterfeld, it was all about money and means of production in the constant presence of the Stasi. After the first successful colour production, the instructions became increasingly strict. For example, Wolfgang Feige and the other employees in the Bitterfeld combine had to cover the entire site of the mill with a barbed wire fence in order to make access more difficult for "Western spies". In fact, cars with Western license plates came and photographed from the outside. It was known that the Erfurt county was secretly researching for a progressive agriculture, and the photographers probably wanted to find out more. In the Bitterfeld combine Wolfgang Feige also produced the first ointments with woad as well as tea and above all paint. The main goal was to produce an ecological colour, but this was only possible after the fall of the Wall and therefore no longer in the Bitterfeld combine.

Through an article in the business magazine "Impulse" the contact came to my father (Hanskarl Freiherr von Thüngen). In 1991 Wolfgang Feige and Hanskarl Freiherr von Thüngen founded the Thüringer Waid Verarbeitungs GmbH (processing) and the Thüringer Waid Forschungs GmbH (research) in Bad Brückenau (limited company of woad processing and research). The former mill was too small, therefore the seat of the company was moved to a former LPG in Haarhausen. In order to produce more woad, the six former LPGs Mühlberg, Apfelstädt, Thörey, Kornhochheim, Ingersleben and Sülzenbrücken were commissioned to grow woad for the products and to propagate the woad seed. Waid Verarbeitungs GmbH had ten employees and Waid Forschungs GmbH carried out laboratory tests. All these were only construction works where no money was earned.

Wolfgang Feige became known through the Waid products and appeared more than 40 times on television, among others on ZDF (second german television), Bavarian Broadcasting, Saarland Broadcasting or Central German Broadcasting. Wolfgang Feige and Hanskarl von Thüngen were also interviewed in Hamburg in 1996 on the red sofa in Hamburg. There Wolfgang Feige was awarded for a recording of his life's work. In 1998 he was awarded a Federal Merit Medal for the television appearances of the Waidaufbau and for the development of the young community of Neudietendorf in the GDR. In 1996 the offices of the GmbHs in Haarhausen were broken into. During the burglary the doors as well as computers and telephones were destroyed and the hard disk with the patents were stolen. The burglary and theft were never determined by the police. Three weeks after the burglary, the stolen patents were re-registered on a Waidmüller GmbH in Munich. Wolfgang Feige and Hanskarl von Thüngen had to process these patent applications for more than 3 years. The result was the insolvency of both GmbHs. For some time before the break-in, LEG Thüringen had sent Wolfgang Feige a chemist with a doctorate in our laboratory, Dr. Müller, to help him free of charge. However, Wolfgang Feige had the feeling that they would want to research the knowledge about woad instead of further researching woad with him and therefore separated from him again.

In 2001, Biotechnologische Anwendungen GmbH (BITA) acquired the commercial exploitation rights for the Thüringer Waidpflanze from Thüringer Waidverarbeitungs GmbH. Mr. Kramer from Bita GmbH in Ahlen bought the patents at the time of insolvency and completely cleared out the former office in Haarhausen. During the

insolvency the patents were taken away from Wolfgang Feige except the basic patent. The basic patent of the trademark is still property today.

Wolfgang Feige has developed a total of 19 products with woad, 12 of which were recognised patents. Insulation protection has not reached the production stage but has got stuck in the experimental stage. There were doubts with possible partners and in the end no companies that marketed the products. However, he says that this would certainly be a different story today with environmental awareness. *(Personal communication, October 4, 2019)*

FIGURE 7: ANKE STILLER

Through her family (Feige) Anke Stiller came into contact with woad, and because of the insolvency of Wolfgang Feige (her father-in-law) the best solution was, that she takes over and continues with the business. Tea, healing cream (ointment) and wood preservatives are still the products in their assortment. She is managing the business from her home and markets the products on a small scale. The woad is obtained from Kornhochheim by the farmer Wolfgang Friebel. All products are still produced very traditionally. The colours are produced with earth pigments, the skin cream from a basic ointment in which the woad leaves are boiled and the herbal tea mixture with a basic mixture of plants from the tea wholesale with our woad leaves as in former times by Wolfgang Feige. *(Personal communication, October 4, 2019)*

FIGURE 8: MATTHIAS HAMBURGER

Professor Dr. Matthias Hamburger is Professor of Pharmacy at the Department of Pharmaceutical Sciences of the University of Basel and was awarded the Alfred Vogel Prize 2004 at the annual conference of the Swiss Medical Society for Phytotherapy for his outstanding scientific achievements. With this award, the Alfred Vogel Foundation honoured in particular Hamburger's research on the dye and medicinal plant Isatis tinctoria. Around 1998, he began scientifically evaluating the properties of the plant, in particular its medicinal properties, with a working group. Initially, Prof. Hamburger's team analysed the historical sources on woad. In a broad pharmacological profiling, the presumed and historically described anti-inflammatory effect of the plant was subsequently confirmed. The next step was to identify and describe the active ingredients responsible for individual facets of the pharmacological profile. In a total of nine publications, Matthias Hamburger and his team documented the manifold aspects of woad. In further 15 publications Matthias Hamburger researched the anti-inflammatory and antirheumatic efficacy and did as well an NMR-Based metabolomic study on Isatis tinctoria which is a comparison of different accessions, harvesting dates, and the effect of repeated harvesting just in 2015. *(Personal communication, October 10, 2019)*

FIGURE 9: WOLFGANG FRIEBEL

Wolfgang Friebel is one of the last farmers in Germany to grow the woad in on the farm in Kornhochheim with special permission but says about the woad himself: "Actually woad is still very widespread in nature but is often not recognized and confused with rapeseed. In fact, the contact to woad came through Wolfgang Feige, already in GDR times. He also cultivated up to three hectares of woad at that time and says that the small area of woad cultivation did not make him rich, but it was very interesting for him. Mainly for the production of woad juice, large quantities of woad were cultivated on the Kornhochheim estate. Wolfgang Friebel was a service

provider for the Thuringian State Institute for Agriculture and cultivated woad for seed propagation and research projects from the state institute. Andrea Biertümpfel, who is working for the state institute also came to Kornhochheim and examined the various woad species in the field. The woad was already sown into rape fields at the beginning of July and the area was staked out. In August rape was sown around the woad fields, because the woad plant carries seeds only in its second year. Therefore, it was sown very early to save one year. Andrea Biertümpfel brought up to 7-8 varieties of woad. The TLLLR undertook many experiments with woad at this time. In the meantime, however, there are probably no longer many of these woad varieties available. The best woad varieties with the best yield and upright growth were sorted out by TLLLR and planted in the Kornhochheim estate. Wolfgang Friebel remembers the number of the most promising woad variety, but as service provider he did not get a detailed insight about the varieties and the research about woad. *(Personal communication, November 11, 2019)*

FIGURE 10: ROSANNA MINELLI

Originally Rosanna Minelli comes from Genoa in Italy but due to her work as a restorer she eventually landed in Thuringia in 1993 via Rome, Lausanne, Bern, Basel, Friburg, Neuschachtel, Geneva, Munich, Chiemsee, Hohenschwangau, Freising, Frankfurt, Görlitz and Naumburg. In Thuringia she worked as a city guide in Gotha, Eisenach, Weimar and Erfurt. She has worked as a restorer for mural paintings and canvas for 22 years. Today Rosanna Minelli lives in Erfurt, where she has been running an artists' and restorers' shop – “a rather special paint shop” - for eleven years. She first became aware of woad in 1997 during a wall restoration in a villa in Erfurt.

Rosanna Minelli established 1997 a shop for restorers, painters and artists, always with the background of having a cultural offer, as this has always been very important to her. Every month a presentation was given to friends and restorers. At first, she gave many of the lectures herself and in addition there were many guest lectures, among others by Wolfgang Feige. Through Wolfgang Feige's lecture in 1997 she learned more about the history and applications of the woad. Rosanna Minelli was

initially disappointed by his lecture on the many different possible applications, but also the major problems in this field and the bitterness associated with them. Wolfgang Feige also said that he had required up to 500 experiments to extract the blue colour. A tourism organisation asked Rosanna Minelli if she could do city tours in Italian and French. After that, she organized city tours in several Thuringian cities, Gotha, Eisenach, Weimar as well as Erfurt and therefor the topic woad was very important. During this time, she was intensively occupied with the history and dyeing of the woad and discovered "the blue" in many ways for the city tours. The program of four Thuringian cities in two days, was a lot of information to record and keep. Therefore, she decided to do something special and combined all her city tours with blue. The woad blue has always caused a lot of "enthusiasm" during the city tours. Through contact with a female dyer on the Krämerbrücke, she made contact with the Neckeroda dyer village. In 2004 she visited the Dyer's Festival in Neckeroda, but was disappointed, because there they dyed with indigo and not with woad. After several guests in Erfurt asked where one could see the famous woad or if one could buy "something", she had to disappoint them, because there was neither a museum about woad, which one could always visit, let alone products with woad. Everything was not constantly available and disappeared sometime. Therefore, she decided to change this and continued to educate herself with literature and researched books, experimented with woad to further educate herself in this field. For six years her manufactory "Erfurter Blau" exists on the Krämerbrücke in Erfurt, in which products with real woad blue are sold. Due to the ideal location, visitors from all over the world come to Rosanna Minellis shop. She notices that there is little research and development in the field of woad in Thuringia. Visitors to her shop ask her how she got to the Thuringian woad with her foreign accent. Consequently, she developed a flyer with basic information about woad, which also states that woad has played a major role both in France and in Italy. She even has contacts in Italy and France with people who grow woad and develop it into products.

Rosanna Minelli obtains the woad from a local farm, which is certified according to Demeter guidelines, as well as from her own cultivation. She can imagine writing a book about woad and founding a woad museum, but she would also need financial support to preserve the old Thuringian history in this way. Valuable for these plans is for instance her interview with the woad expert and woad historian Horst Benneckenstein, who passed away. *(Personal communication, November 11, 2019)*

Personal communication has also been conducted with experts of specific areas important for the exploration of business ideas of the woad plant:

Gerwin Stein: German Centre for Crafts and Monument Conservation in Fulda; Probstei Johannesberg; (Deutsches Zentrum für Handwerk und Denkmalpflege in Fulda) *(Personal communication, October 15, 2019)*

Dipl.-Chem. Martin Mach: Main Conservator / Head of the Central Laboratory of the Bavarian State Office for Monument Conservation (Hauptkonservator/Leiter des Zentrallabors; Bayerisches Landesamt für Denkmalpflege) *(Personal communication, October 18, 2019)*

Hanskarl Freiherr von Thüngen: Business partner of Wolfgang Feige in the TWV and TWF. He renovated the buildings of his home with woad in 1996. *(Personal communication, November 8, 2019)*

Information from Interviews out of the documentation from Dagmar Langanki: Feiges Blaues Wunder in 1996:

Professor Rudolph Ziesler: Former State Conservator of Thuringia

Werner Haase: The architect used woad products for renovations

6.2 INTERVIEW ANALYSIS AND INTERPRETATION

THE PLANT WOAD AS AN ECOLOGICAL BUILDING MATERIAL FOR FACADE PAINTING, WOOD IMPREGNATION AND SANDSTONE SEALING.

Wolfgang Feige: *“Wood preservation has already been developed the most, which is why I see it as the greatest opportunity today. Also, the ecological colours could be interesting, because of the environmental awareness. The problem with sandstone sealing is that it has not really been researched yet.”*

This statement of Wolfgang Feige gives a brief overview of the current situation of ecological building materials. The existence of insecticidal and fungicidal effects of woad are confirmed in different research projects for example by Renate Kaiser-Alexnat. *(Kaiser-Alexnat, 2014)* Wolfgang Feige tested the effects already in the 1980s on wormed birch wood with untreated pure woad juice, which later developed into his wood preservative product. Only after that came the development of the different

colours. The colours are earth pigments mixed with woad juice. Wolfgang Feige and his son Albrecht Feige painted some houses with the colours and there were even more orders after the preservation of monuments in Erfurt became aware of the colours. “Wolfgang Feige explains that the houses have been standing for 25-30 years and they appear to be in very good condition. The strong smell (stench) of the colours could never be completely removed by Wolfgang Feige. Also Professor Rudolph Ziesler former State Conservator of Thuringia confirmed in the documentary “Feiges Blaues Wunder” from the MDR in 1996 : "In Erfurt we have a whole range of objects, such as the “Haus zum Güldenen Krönbacken”, a house in the Andreas street, and many more objects where woad products have been used. In cooperation with the Deutsches Zentrum für Handwerk und Denkmalpflege (Centre for Crafts and Monument Conservation) in Fulda, we have been laying out weathered woods starting from 1992, i.e. wood that has been treated with woad products, painted, in various versions, in aqueous solutions, bound with wax and in various colour shades. These coatings have always been associated with conventional wood preservatives, only to have a comparison in terms of long-term effectiveness. This weathering is further carried out, the developments already protocoled. The test series, which have started are extraordinarily successful and also show an enormous superiority over normal chemical products.” *(Langanki et. al. 1996.)*

During a project to paint a church facade in the Thuringian Forest, the responsible architect suggested to the painter Wolfgang Feige to treat the sandstone with woad. *(Wolfgang Feige: Personal communication, October 4, 2019)* The sandstone had to be cleaned and it was previously planned to strengthen it with chemical agents. But they used the pure woad juice and mixed it with some lime. This was the first sandstone to be preserved with woad. *(Wolfgang Feige: Personal communication, October 4, 2019)* Before 1990 already 200 buildings in eastern Germany were painted with woad, however not only by Wolfgang and his son Albrecht Feige, but also by other private people and other painters. But not everyone was satisfied because of the strong smell of the material during the first weeks. Probably because of the mixture with lime the material for the sandstone stopped smelling faster.

Anke Stiller, who is the daughter-in-law of Wolfgang Feige, is one of the rare producers of woad products. She produces the following products: Thüringer Waid wood primer, Thüringer Waid thatched roof impregnation with fire retardant effect, Thüringer Waid

masonry impregnation, Thüringer Waid anti-moss, Thüringer Waid deck paint for wood coatings, Thüringer Waid wood varnish. All these products can be purchased directly from Anke Stiller or on Andreas Breuer's website Ecological Building Materials. *(Ökologischer Baustoffhandel - Thüringer Waid, 2019)*

The architect Werner Haase has already used woad products several times for renovations and reported in the documentary “Feiges Blaues Wunder” from the MDR 1996 about the advantages of the woad: "With our office we build relatively much with monuments and redevelop these and have thereby often the problem, that we look for coatings, which are in the similar technology, as it was made in former times before substitutes or plastic colours or similar products came on the market, since the colours must be compatible with each other. In the past, there was a lot of work with lime paints (varnishes etc.) and we were looking for natural products that could do this nowadays and have only worked with lime up to now. We came across the old woad colour by chance and have already used it several times. So far, we have had very good experiences with it, the craftsmen are usually also satisfied with the processing possibilities. For us, the great feature of the woad colour is that it is a very soft, pleasant colour that is otherwise very difficult to mix. We have already used the colours several times and had very good experiences.” *(Langanki et. al. 1996.)*

Hanskarl Freiherr von Thüngen has been dealing with renewable raw materials for many years and thus became a shareholder of Thüringer Waid GmbH. When the castle in Thüngen was to be restored and renovated in 1995, it was clear that only woad products would be used: "For me it was crucial that such an old building, when it is renovated, is treated with the materials that were previously used. There were few possibilities, after a long research one came back to the old traditions, the Thuringian woad is one of those renewable raw materials, which one appreciates today in the monument care very much. I as a builder have insisted that the woad is also used here. For me as a resident of this house it is crucial to use healthy materials, as everybody, especially children, come into contact with the building. I have already had to maintain many buildings in my life, more of a burden than a pleasure, but I have learned one thing, if you have used the wrong material, you have had to repaint it in a few years and therefore, must pay for it. I think here, with the experiences we have made with woad so far and which also exist in Thuringia for a long time, one can probably assume that in my generation this castle will not have to be renovated again from the outside.

All this thanks to “Thüringer Waid” and Wolfgang Feige! In this way, the preservation of historical monuments builds a bridge for the woad into the future by remaining historically correct and renovating medieval buildings with contemporary materials, fulfilling all the criteria of ecological building and thus being absolutely up-to-date.”

Rosanna Minelli says: “As a wall paint for interior painting woad certainly has potential, since the special blue colour is very much in demand in my experience.”

In Erfurt, 400 years ago, the production of paint in the woad stores had already "unconsciously" impregnated the wood with woad. *(Rosanna Minelli: Personal communication, November 11, 2019)* One sees in the old woad warehouses, where the woad juice and the urine/ammonia have run down. This continuous impregnation with woad juice took place more than 400 years ago without interruption through continuous production. For Rosanna Minelli as a restorer, this is a difficult subject as there is no research on the real differences in the use of woad compared to other similar products in the restoration field. The question is also how deeply the woad impregnation can penetrate the wood, if it is not constantly impregnated again, as was the case in the Middle Ages. In addition, the woad is very sensitive and mobile. Another problem is certainly the amount of labour costs for such products.

THE CHANCES OF WOAD AS A TEXTILE DYE ON THE TEXTILE MARKET.

Rosanna Minelli: “I can imagine very well great opportunities in the field of fashion for textile design, because the blue colour is very special to a lot of people. A necessary prerequisite is a large network in which the full woad value chain is used also for other products. In France, Austria and Italy there is a small fashion line within the textile industry. This could also be expanded in Germany, for example a farmer would plant the woad and I would extract it together with the farmer. In France they are further developed in that area, a farmer harvests alone and processes a ton of leaves a day. In France, ten years ago, 19 ha of woad were still cultivated. The woad was obtained for the extraction of the indigo dye by extraction. This dye was used for fashion design.”

“Personally, I love the woad blue! I bought a silk cloth dyed with woad indigo from Rosanna Minelli of the woad manufactory "Erfurter Blau" on the Krämerbrücke in Erfurt”, says Renate Kaiser-Alexnat.

Even though on a large scale most of the interviewees are agreeing, that due to the low dye content in the leaves, woad as a textile dye is difficult to compete with indigo and other plants for blue colouring with higher dye contents, there are chances. Reusing the local woad for textile dyeing is an idea of historical value and good for workshops, but a niche production.

The chances of successfully managing this application on a larger scale are small and therefore it is more a project of historical value for the woad. “Nevertheless, everyone can see and experience “Erfurter Blau” from Rosanna Minelli is a great project and very beautiful products can be produced and marketed” adds Susanne Frenzel. According to Renate Kaiser-Alexnat’s personal opinion, the market for textiles and other products dyed with woad indigo is more or less limited to lovers of woad. The Krämerbrücke in the “woad city” Erfurt, which is heavily frequented by tourists, is a predestined location for products dyed with woad indigo, because Erfurt is associated with the woad due to its history. Whether people are enthusiastic about it is not only a question of pleasing, but also of enlightenment and marketing.

THE FUTURE OF WOAD IN MEDICINE AND COSMETICS.

The healing and protective effect of the woad products has already been mentioned as well as their environmentally friendly production. In addition, it should be mentioned that woad cultivation barely requires the use of chemicals, since for the hardly overbred plant there are only few problems with diseases and pests, also due to the frequent harvest of woad leaves. Hence, it is not astonishing that beside the chemical industry also the scientists are showing great interest into researching the “secrets” of Isatis tinctoria. Most of the research in the last two decades was about the medical features of the plant. The effects and features as well as the ingredients of the woad plant have been researched with a lot of different projects.

Professor Matthias Hamburger from the University of Basel is one of the best known and most important experts for medical research on the woad plant. In Basel he worked on woad, which has very interesting ingredients for him and interestingly a botanically very close relative in TCM, Isatis indigotica. In Basel, Woad was investigated very intensively, in order to really work out systematically and exemplarily how one could actually make a Denovo development with the today's methodical possibilities, up to a

product development. The results were about 25 publications, several patent applications and a PCT procedure, i.e. an international patent application.

“The pharmacy has made great progress, which could also enrich phytotherapy.” says Professor Matthias Hamburger, however, he is not optimistic about the future, because the results are not realised as products. “We have done the entire phytochemistry, we have characterised the extract down to the last detail and we have also carried out comparative studies on the cultivation level on the origins and seasonal changes in the ingredient patterns. We have done pharmacology - in vitro we have characterised active ingredients and animal pharmacology. We have gone up to a clinical pilot study in dermatological application. And actually, everything is wonderful. That's where we stand now, but I am not getting any further.”

Susanne Frenzel, who is currently building a network for the woad plant has her own view about the pharmaceutical and chemical industry: “In my opinion, something is going wrong fundamentally, in the pharmaceutical and chemical industries. In this industry the analysis of the ingredients is researched to such an extent that they could also be produced synthetically. If empirical research would suffice more as proof, woad would be brought more easily onto the market, because the proof of the effect of the multi-component mixture is clear.”

The reason for that are two major hurdles, the regulatory framework for drug approvals and the funding of this research. “Before the clinical approval, about 2 million euros have to be invested in the regulatory framework. Only then it would be possible to enter a clinical phase”, assumes Matthias Hamburger.

This is a general problem in the pharmaceutical sector, even in clinical studies, even if large companies are encouraged in this field, a large number of active substances are falling out. In these cases, however, 100 million or more have already been invested, depending on how far the studies have come. This is clearly a really big investment. That is the reason why I have stopped research.”

Wolfgang Feige became aware of the anti-inflammatory, antimicrobial and haemostatic and astringent properties and effect of the woad when he cut himself quite deeply into the skin with a sickle during the harvest of the woad in the middle of a field. To stop the bleeding, he tied woad leaves with a string around the deep wound and by the time he arrived home 30 minutes later the cut had grown over. This healing effect of woad

is also mentioned in antic sources *(Wittstein, 1881)*, is confirmed through investigations by Dr. Mekwasil, a dermatologist and head physician of the clinic in Nordhausen in the 1980s. Due to this development the extension for the production of an ointment was decided and the cosmetic research with the woad plant began with the company Nuth Chemie GmbH & Co KG. All this happened in the last years of the GDR. In 1992, the company Nuth started to intensify the research and development of cosmetic products with extracts of the Thuringian woad plant in the field of natural cosmetics. At present, a complete range of cleansing, vitalising and care products is available from Nuth and Waidea, which is a partner company of Nuth. Furthermore, there are two cosmetical products from Dermasence on the market, which use the anti-inflammatory and anti-irritant effect of woad: Vitop forte, an intensive care cream for neurodermatitis and Barrio Pro cleansing foam, an anti-irritant cleansing foam. *(Dermasence, 2019)*

“The woad oil would have a great potential, if one gets the authorisation for medical products. As a cream for neurodermatitis, woad has successfully established itself on the market. In Jena, the effect on nail fungus was researched at the university, but research does not seem to be continued here.” Susanne Frenzel.

Wolfgang Friebel means: “I see the opportunity, but the question is to what extent synthetic production is already possible. If it is cheaper, the woad plant will have no chance.” Wolfgang Friebels assumption of the synthetical produce comes from the question where the natural woad for cosmetical products of certain companies should come from.

Rosanna Minelli: “In my opinion, woad oil has great potential even when processed into cosmetic products such as soap. The skin does not dry out. This year I started to test an ointment enriched with woad oil, which is produced by my pharmacist. The ointment is used for neurodermatitis and very dry skin and has so far been very well received by users.”

WOAD FOR BIOGAS OR AS AN ECOLOGICAL INSULATING MATERIAL.

When it comes to woad straw for biogas plants, all experts agree that theoretically a large number of plant materials can be used in a biogas plant. The woad straw only accumulates after a longer vegetation period in the second year of cultivation and the straw yield is not productive compared to fast-growing grasses. Moreover, the amount of raw material produced by woad in terms of stems is not as high as the raw materials

produced by another mass-producing plant. In addition, the woad straw is very firm and therefore probably not easily degradable.

Susanne Frenzel: “As an ecological insulating material or as pressed straw bales, it would be a very interesting idea, as straw bale houses could be built with the building materials clay and lime and would also have an absolutely natural product.”

Wolfgang Feige: “A customer in Northern Germany wanted to test the application of woad on thatched roofs. In Neudietendorf it was demonstrated at the woad festival with up to 4000 guests. With the fire brigade a thatched roof was coated with woad and another thatched roof was soaked with woad juice. The soaked roof was dried and then burned by the youth fire brigade. However, it did not ignite a fire, only burn marks. But the woad-coated roof burned slightly.” As insulation, thatched roofs impregnated with woad juice would be a good application. The pressed woad is not only fireproof, but also very durable. For this application, the woad juice and leaves and the woad straw from the two-year woad were used.

Wolfgang Friebel: “In the context of fire retardation, there could be a chance if more research is done into the effect. However, it must also be seen here that production as a whole must be worthwhile. Here one could work with percentages, 10% for example in the wood construction industry etc. - but I don't see any chance at 100% for the produce as an insulting material.

WOAD AS A BIOLOGICAL PESTICIDE OR BIOLOGICAL HERBICIDE IN THE AGRICULTURAL MARKET.

Renate Kaiser-Alexnat answered to the question if she can imagine that woad as a pesticide has a chance in agriculture on the basis of her greenhouse experiments, which she carried out on a small scale as preliminary tests to confirm the allelopathic effect of the decomposed woad fruit: “My publication in the newsletter of the German Plant Protection Service is based on pot experiments, which I carried out on a small scale in greenhouses to confirm the germ inhibiting effect of the woad pods with very high application rates. This should have been the basis for a larger scale research project. However, the application for research funds did not lead to the desired success, whereupon I published the results obtained so far, despite the small scope of the experiment, so that they could be preserved for posterity and possibly be further researched at a later point in time.”

“In the meantime, my hopes have been put into perspective and I think it is rather unlikely that the allelopathic effect of decomposed woad fruit will have a chance as a biological herbicide in practical cultivation. The quantities required for soil application would have to be extremely high in order to achieve the germicidal effect proven in pots under greenhouse conditions. This would be extremely expensive and therefore uneconomical.”

In addition to the experiments with decomposed woad fruits to prove the inhibitory effect on the germination of seeds, laboratory tests were also carried out at the Institute of Biological Plant Protection in cooperation with various colleagues on the effect of fresh and fermented woad leaf juice on various pests and plant diseases. The investigated target organisms are listed in my publication in the proceedings of the “7th Waidtagung in Pferdingsleben”. During the mentioned preliminary experiments with regard to a potential research project, the effectiveness of leaf extracts of the woad could only be proven in seed-born fungi of the carrot (Alternaria radicina, Alternaria dauci). ***(****Kaiser-Alexnat, 2013)*

If the research funding for the planned research project was "Evaluation of the glucosinolate myrosinase system in the woad (Isatis tinctoria L.)" would have been successfully applied, Renate Kaiser-Alexnat would have conducted further research:

“As a plant breeder, I was interested in an evaluation of the woad with regard to the genetic variability of the glucosinolate myrosinase system. Since the glucosinolates are the starting substances for biocidal degradation products and the degradation is catalysed by the myrosinase, it can be assumed that the content and composition of the glucosinolates as well as the myrosinase activities are the key factors for biocidal efficacy. In addition to the corresponding biochemical investigations, the biocidal efficacy against the most important target organisms should be examined in the agar diffusion test. Genotypes with a particularly high biocidal potential should be selected on the basis of the results of the biochemical investigations and the efficacy test. In order to gain further important knowledge for the agricultural production process of the intended use direction "biocidal efficacy", studies of the glucosinolate content and the composition of the glucosinolates as well as the myrosinase activities in different plant organs and development stages should also be carried out.”

Insights into which chemical substances are responsible for the antibacterial effect of woad are not clarified: “In the already mentioned publication in the newspaper I had stated in the discussion: Which chemical substances are responsible for the germ-inhibiting effect of the woad pods has not yet been clarified. Presumably the germ-inhibiting potential is based on glucosinolates, the degradation of which leads to allelopathica. Which glucosinolates occur in the fruit tissue of the woad and which biologically active compounds are formed during enzymatic degradation remains to be clarified.”

In order to differentiate whether the germ-inhibiting effect can be attributed to the seeds or the pods - i.e. the fruit tissue -, the glucosinolate contents in the corresponding plant parts were investigated in 2010 in cooperation with Dr. Wolfgang Schütze from the Julius Kühn Institute. For this purpose, the seeds were separated from the pods and separately processed and analysed. The glucosiolate contents in the pods were very low at 2 µmol/g TS, while those of the seeds were very high at 154 µmol/g TS. The main glucosinolates were progoitrin and sinigrin. Their high concentration, i.e. the formation of isothiocyanates after myrosinase cleavage (ITC, mustard oils; only sinigrin, progoitrin does not form ITC) probably leads to germ inhibition (personal communication, Dr. Wolfgang Schütze, 2010). These results were presented at the 7th Waidtagung in Pferdingsleben and further details are presented in a table in the corresponding proceedings.

Andrea Biertümpfel: “The same applies to pesticides as to cosmetics and medicine; intensive preliminary studies are required to use woad as a pesticide. One possibility might be to use woad as a plant strengthening agent, for example like knotweed is used, in some products of Neudorff or Nufarm (combo products). The authorisation to produce and retail plant fortifiers is easier to get than for pesticides. Pesticides require the same effort as drugs. As I said, studies on efficacy, studies on harmlessness, among others and here I do not see who could bear the financing costs.”

Wolfgang Friebel: “If one has the chance to achieve something through the allelopathic effect in ecological cultivation, I see in plant protection the great chance of the woad.”

PERSONAL STATEMENTS OF THE WOAD EXPERTS IN WHICH MARKET WOAD HAS THE HIGHEST COMPETITIVE ADVANTAGE

Renate Kaiser Alexnat: In connection with a very good marketing I see the biggest chances for the practical application of woad in the production of woad indigo and its processing in various products, as it is practiced in Germany by "Erfurter Blau", in France by "Bleu de Lectoure" and in England by "The Woad Centre". On my homepage "Institut für Färbepflanzen" I maintain a data sheet with woad products (see http://www.dyeplants.de/pdf/Waidprodukte.pdf) in which these and other suppliers of woad-based products are listed alphabetically. As a "direction of use" for the woad not yet mentioned, I recommend surrounding yourself with woad plants, because I have observed that the woad has an inspiring effect. In intensive and stressful times, because of publications, I sometimes put a pot with woad plants on my desk. When it came to individual formulations, I looked at my woad plant questioningly and then the best ideas came to my mind!"

Susanne Frenzel: "The difficulty in all areas lies in the authorisation of the products. If you get certification in the field of building materials, that would probably be the most likely thing."

Andrea Biertümpfel: "The fact is that you still have to undertake many studies and find people to finance these studies and works. The experts who would carry out the studies would have to be hired, as someone would have to raise the money. Usually, if a company does this on its own initiative, it will also calculate a corresponding sales volume. Somehow the money has to come in again, so I see the problem in the financial area."

Wolfgang Feige: "Wood preservation has already been further developed, which is why I see the greatest opportunities here today."

Anke Stiller: "In wood preservation and medicine and Waid, in my opinion, has great potential, but this medical development must be undertaken by pharmaceutical companies. In this area there is already research in clinics against cancer and the medically interesting ingredients of woad, for example from Professor Hamburger."

Matthias Hamburger: "Of course, in the end it is always a question of generating an extract that is more optimal in its composition than what has perhaps been on the

market so far. Extraction technology offers potential. In principle, from a purely methodological point of view, there are many possibilities that are currently not being exploited. This also has to do with the regulatory environment. If, for example, lipophilic substances are present in a plant, it would make sense not to generate a full extract, but simply to extract these more lipophilic substances selectively. This is what CO2 extraction is for. The technology works and has been used on a large scale e.g. in the food industry for years for various processes to extract flavours and colourings or to decaffeinate coffee. If they are used in the phyto area, the regulatory hurdle comes again, because you no longer have full extracts, but a New Herbal Entity. You have to get a full approval for them again - and that's extremely expensive." *(Meier et al., 2012)*

In vitro, in vivo you can show a lot and I believe that the data we researched at Isatis tinctoria were very promising. Unfortunately, this is no guarantee for anything, for nothing at the end. If in large pharmaceutical companies, all the data, everything they have, could be converted one-to-one into clinical efficacy, then the world would be saved 100 times. Of course, to put it rather casually. But that' s the way it is basically, I was in industry for a few years in research. It is a difficult business and the approvals for a novel herbal drug that are as high as for a recombinant antibody, for instance, are extremely expensive.

Wolfgang Friebel: "I have to answer that very clearly. The woad will have no chance if something is not politically and scientifically put straight. The prerequisite must be created that one is supported politically and scientifically for a project with woad. Nutrition, allergies and many other areas - what is the possible role of the woad? I t is certain that woad has insecticidal and fungicidal effects, as the Germanic tribes have already stated, - then why not deal with it? But here science and politics have to participate. Until now, with woad it was always only a short period in which something happened, but continuous development, unfortunately did not happen so far."

Rosanna Minelli: "In the worst case, "Erfurter Blau" dies with me. Hopefully I will find someone who will continue "Erfurter Blau", because the idea is good, and I have already learned and researched a lot, but there is also much more to explore in the field of dyeing. I think that in medicine and dyeing there may be opportunities for the future. I can also very well imagine that there are great opportunities in the field of fashion for textile design and for painting. Pigments would have to be extracted for painting. However, in this area one is also dependent on the weather with regard to

the colour precursor contents. My dream would be to be able to start a project in which I could research about woad and would be financially supported. In recent years I have observed that the warmer and drier climate in Germany has led to higher indigo content and darker blue tones in woad. I see an opportunity in building a network to create a good value chain for woad to use all parts of the plant for different functioning business areas."

6.3 OTHER POSSIBLE WOAD APPLICATIONS

Food: "I have already eaten salad, but only the young woad leaves. However, the large woad root could also be used as food, but I have no experience with this", says Wolfgang Feige. However, in 2018 a study about the phenolic profile, antioxidant and cytotoxic properties of polar extracts from leaves and flowers of Isatis tinctoria L. (Brassicaceae) growing in Sicily was published, which records that woad was used as food for humans. *(Taviano et al., 2018)*

Supplements for animal nutrition: Susanne Frenzel believes that a feeding experiment could be very interesting - in other words, an experiment on the use of woad as a fodder plant. As with food, however, there are hurdles to be overcome in terms of the registration procedures, when it comes to fodder plants. There has been a study of the Institute of Animal Nutrition (Institut für Tierernährung), Friedrich-Loeffer-Institut (FLI) and the Federal Research Institute for Animal Health (Bundesforschungsinstitut für Tiergesundheit). This study from 2008 based on the research of woad, assuming woad might be useful to prevent cancer, because it contains 20 times the amount of glucobrassicin than in broccoli. *(Galletti et.al., 2006)* The aim of the research study was to identify the effect of a diet supplement with woad or ginkgo on broiler performance. *(Halle, et al., 2008)*

Wolfgang Friebel sees feeding as an opportunity, also due to the recent confirmation of the cooperation between farmers and veterinarians. As a result of the development towards organic farming, more problems with fungi and more problems with mycotoxin will occur, so natural pesticides must be found.

For the animal nutrition Wolfgang Friebel can imagine the following process: "The wheat and rye grain must be polished thoroughly, then the grain must be moistened, in order to be able to peel it, in order to uncover the flour body. The grain is peeled and

somehow the damp peel must connect with the mycotoxin. This closes the cycle from the animal (especially the pig) to the human, who eats the animals at the end. For a project like this you need powerful partners like the Animal Disease Fund also to provide the legal certainty."

"Due to the antimicrobial effect of woad, it would be quite conceivable that in this day and age we could see the chance for healthier animal husbandry with less use of drugs. In addition, other plants from the same plant family are on the list of approved forage plants, so this could also work for woad. The root of Isatis indigotica is listed as a medicine in traditional Chinese medicine and is used as a food supplement" thinks Susanne Frenzel.

Liquor: Wolfgang Feige: The whole plant can be used up to the root to make liquor. With liquor, the roots were delivered and cleaned and crushed. Then it is mixed with alcohol. It tastes like gentian liquor. Also, for this application they had a patent together with the distillery.

7 DISCUSSION

The discussion chapter will delve into the importance and relevance of this research project. The aim is the explanation and evaluation of the researched data from the empirical material and connecting it to the literature review as well as the research questions. This section is divided into four major key elements, the interpretation of the research, to indicate the results. The implication of the work to explain the meaning of the results. The Limitations of this thesis and finally recommendations for further practical actions or scientific studies. The construction of the discussion chapter leads to an argument for the overall conclusion.

7.1 INTERPRETATION AND IMPLICATION

The interpretation and implication of the researched data is also a review of the research aim and objectives and takes a look on all the different markets and its woad products.

On the market for building materials only a few woad products exist. In terms of ecological building materials woad products could not be profoundly established, even though the products are promising. The reason for that is, there is hardly any marketing for these products and for a greater market entry not enough official proof of concept exists from renowned companies or institutes.

The promising project financed by the DBU and conducted by the three partners TWV, TLL and HKI did not evolve into a successful business. The main reasons for this unfavourable development was most likely not due to the results of the project, but a burglary of paperwork containing the patents of the TWV for the wood preservation products. This caused financing problems, because new, very similar patents were applied in Munich after the burglary and the wood preservation products had to be withdrawn from the market.

The wood preservation products of the TWV have been tested from 1992 for four years by the DZHD in Fulda on a weathering stand, together with other chemical wood preservation products. The results of the weathering projects can be implemented if an introduction of wood preservation products out of woad for the ecological market is planned. The DZHD has just started a new weathering project on the initiative of the advice centre and the working group of restorers in the crafts sector, in which 20

different coating systems on wood with a focus on linseed oil paints are investigated. The Thuringian Waid coating system for wood, which is available online on the website for ecological building materials, is also included in this project. *(Gerwin Stein: Personal communication, October 15, 2019)* The involvement of the Thuringian Waid coating system in the new weathering project from the DZHD is an outcome from this thesis. The involvement establishes the possibility to compare the new project to the weathering project from 1992. Moreover, the research results could provide the opportunity for introducing the product to the market of the conservation of historical monuments.

The healing effects of the woad plant have been researched in numerous studies and the efficacy of anti-inflammatory, antimicrobial, haemostatic together with astringent effects are proven in “in vitro” and “in vivo” studies. However, the pharmaceutical industry is very cost intensive in terms of new products, especially when it comes to new herbal medicinal products. The reasons for that are arising expenses for the four steps of clinical studies. Even before that, the expensive regulatory toxicology for a new herbal entity must be financed, to which the woad products would belong, if for instance the detailed studies of Matthias Hamburger would have been realised as products on the market. So far, no company was prepared for financing and taking the risk of a woad product to the pharmaceutical market. In China, the root of the Isatis indigotica (banlangen) is sold in pharmacies and is an accepted medicine for the TCM. Interestingly, in the last years Chinese companies submitted a couple patent applications for Isatis tinctoria to the European market.

The analysis of the cosmetical products out of woad confirms that on this market a couple of companies could successfully place their woad products. The products range from skin care products to neurodermitis skin care. An immense difference are the regulatory requirements, which are less controlled and extensive for biological cosmetic products.

Woad has promising phytosanitary attributes, which have been researched in order to explore its function as a biological herbicide and pesticide. The germination of seeds is inhibited due to allelopathic substances, which are set free upon the rotting of the fruit of woad. Renate Kaiser-Alexnat conducted a study based on pot experiments under greenhouse conditions with the introduction of decomposed woad fruits into the soil. The aim was to find out how much of the woad plant is used and how strong the

inhibitory effect of weed control is on the germination and young plant development of selected weeds. The study proves that the germ inhibiting effect is present, but for field conditions the applied form of application is too expensive. *(Kaiser Alexnat, 2014)* Still, the allelopathic effect could be of interest for certain applications such as biological plant protection, especially with fewer possibilities of conventional plant protection due to stricter laws for plant protection.

All the experts agree that the woad plant is not a suitable for using woad for biogas production, because there are better alternatives such as maize. Furthermore, the cultivation of woad for biogas production the ingredients of the plant are too valuable for other applications. Woad as an insulting material has not been researched yet, but in combination with the proven fire-retardant properties of the woad plant, this business idea could be successful. Certainly, for this kind of application more research is required to have a profounder evidential basis.

The extraction of woad blue from the dying plant is the most famous application and of historical importance for Europe. Although synthetic colours are the main source for textile dying nowadays, the demand for natural dyestuff is rising again, because of a changing consumer behaviour, in which environmentally awareness is more important. For the extracted woad blue, however, the demand for textile industry is insignificant, but there are dying experts especially in France and also in Germany like Rosanna Minelli from Erfurt, who keep the extraordinary art of dying with dyers woad alive and produce products, which also have traditional value.

For the application of woad as food for humans or as supplements for animal nutrition, only a few research projects have been conducted so far. The most recent one in Italy investigates the leaves and flowers of the woad plant, which have been used as food for humans in Sicily. In a study from 2006, it was discovered that the woad plant contains 20 times more glucobrassicin than in broccoli. Glucobrassicin is claimed to have anti-cancer agents and vegetables with a high amount of glucobrassicin are recommended by researchers to bring health benefits. As a matter of course, more research and further cost intensive clinical studies need to be carried out before it is possible that plants like Isatis tinctoria can play a part in the prevention and treatment of cancer. Glucosinolates (= mustard oil glycosides) are mainly found in plants of the cruciferous family (Brassicaceae) - horseradish, radish, cabbage and watercress are known as medicinal plants. Nasturtium is also used in phytotherapy. Mainly the

vegetable plants of the genus cabbage are also interesting as food, because of their content of mustard oil glycosides. In this respect, broccoli (= broccoli, Brassica oleracea var. Italica) has been intensively researched in recent years.

These results should be taken into account when considering how to start a business with woad, because the possible applications of the plant with its various features have been discussed in detail with eight woad experts. The data provides a clearer understanding of how important the inclusion of research and politics is when planning to build a business with woad. The last 30 years show that in Germany only a few businesses were able to make something out of this plant, which means that the goals of some business ideas were very difficult to fulfill or disturbed by external factors. This shows that, in theory, a lot of ideas sound very promising, but in reality, the specific conditions for each application need to be observed very clearly. While previous research was mainly focused on the research of the woad plant with its special features, these results demonstrate that for further planning until the stage of product development, one needs to put the theory into practical context, if it is realistic to start a business, concerning the competitive advantage of the woad products, the political situation, the registration conditions as well as the costs.

7.2 LIMITATIONS AND RECOMMENDATIONS

The generalisability of the results is limited by the existing research which is mainly about the theoretical applications without the specific registration conditions and limits of each market. The use of woad as a wood preservative, for example, was already realised on buildings and the products have also been researched. But there is still the limit if wood preservative products with woad will meet the registration conditions nowadays. One problem is, the research projects about this topic were conducted 20 years ago, which means there are new products on the market and the problems of the earlier projects are causing concerns. The uncertainty nowadays is also caused by the question of what caused the failure 20 years ago: either the product, which is rather unlikely since for example the buildings, on which woad products have been used still have no significant wear and tear from an unscientific perspective. This perspective is very limited since no research has been conducted for the proof of the concept or expert examinations for legal effectiveness. On this topic research is clearly limited

and the questions is if the already established business ideas, which could never be realised would work nowadays.

For further research for natural plant protection with woad the key factors for biocidal efficacy have to be discovered. Renate Kaiser-Alexnat assumes that the content and composition of the glucosinolates are the starting substances for biocidal degradation, which is then catalised by the myrosinase activities. Besides the biochemical investigations, the most significant target organisms in contradiction to the biocidal efficacy should be investigated in the agar diffusion test. Furthermore, Renate Kaiser-Alexnat suggests, that the genotypes with a particularly high biocidal potential should be selected on the basis of the results of the biochemical investigations and the efficacy test. For the agricultural production process of the intended use direction "biocidal efficacy", further research has to be conducted on the content and composition of the glucosinolates. Additionally, an investigation of the myrosinase activities in different plant organs and development stages should also be carried out.

Wolfgang Friebel has insight-knowledge about business plans and ideas with woad, due to the fact that, since the rediscovery in the GDR in the 1980s, he always planted woad. If people wanted to start a new business with woad, Wolfgang Friebel often was the reference person, first of all to gather his knowledge and most of the times also to get woad seeds, woad leaves or woad juice. According to Wolfgang Friebel, before starting a business with woad, the most important factor is to connect and discuss with partners in the political, scientific and industrial area about all regulatory registrations and the political situation concerning the business. This research provides an insight into the importance of the registration procedures and the political dependency for new products. Future studies about business ideas or strategies for woad should take into account the registration procedures and especially the political conditions keep changing. It is beyond the scope of this study to evaluate the chances, if the business ideas will or can be developed into business strategies and in the end, be established successfully on the market.

8 CONCLUSION

8.1 METHODOLOGICAL REVIEW

The qualitative research method was an effective method for answering the research questions because it allowed an in-depth approach on the topic. As research design the case study model was chosen, for the reason, that it provides an in-depth look into the exploration of business ideas of the woad plant. The model permits the researcher to obtain individual, related, insightful expert knowledge to investigate the implications and key characteristics of this case. The empirical data of research project was based on interviews with a group of eight woad experts. For finding interview participants with an insightful knowledge about the woad plant the sampling procedure was a non-probability method together with snowball sampling. Several of the eight interviewees conducted research projects and have published literature about the studies concerning the woad plant. All of the participants have investigated the woad plant and certain experts have gained their insight knowledge due to their profession at universities, in the pharmaceutical industry, as a farmer, master painter/craftsman, restorer and textile dyer. As a data collection technique, personal semi-structured in-depth interviews with one respondent at a time were conducted. The interviews were conversational and included open-ended, unstructured questions. The interview participants were asked six questions in one-on-one, semi-structured interviews, which proved to be an efficient approach for gathering data to meet the research objects. For acquiring a profounder knowledge regarding a woad product, specific market and the competitive advantage of woad in the market, the model was an ideal opportunity, because the woad experts had the freedom contribute detailed information. Another advantage of the interviews was, that the investigator could collect meaningful data with asking the right questions and for further information follow up questions, that helped to get a more detailed answer for the research questions. The analysis of the interviews the data was organised structured into six topics and interpreted to explore the key findings and themes. The researcher is aware of the ethical considerations and followed them in this research project.

8.2 OVERALL CONCLUSION

This study investigated business ideas of the woad plant on different markets. The different features of the woad plant for various application made the research project very diverse. The results of the collected data indicate that in general all the interviewed woad experts agree that the woad plant has special ingredients and effects for different applications. The study builds on existing research about the insecticidal, herbicidal, pesticidal, healing, nourishing and dying effects of the woad plant. Regardless, just a few of the applications to which research and studies have been conducted could have been realised as a product on the market. Astonishingly in Europe, only the cosmetical market and the textile market are worth mentioning, when it comes to industries with successful woad products. On the one hand, this sobering realisation demonstrates that the market entry of woad products is challenging, not only for historical reasons, since some business ideas started in the GDR shortly before the fall of the Berlin wall, but also because of cost intensive regulatory requirements for specific markets. On the other hand, the enormous efforts that has been put into specific explorations of the woad plant continuously captivates people, as promising research approaches and results in very different markets have been conducted. Wolfgang Feige deserves the credit for having shown this field to research. This study demonstrates a correlation between the interviewed woad experts, and therefore shows that there are only a few people who followed up and researched about woad. The difficult conditions for a market entry of environmentally friendly and natural woad products, might change in the upcoming years, because environmental awareness of the consumers is increasing, which is beneficial for renewable plants. Renewable natural substances pose innovative questions to science and therefore, it is the task of research to apply modern methods to find out under which conditions the optimal active substances of plants can be developed and found. Additionally, the investigations have to explore how the substances can be introduced into a process, which would optimise the chances, that also under industrial conditions a good active substance can be found and marketed.

By reviewing the typical uses of woad as an ecological building material Wolfgang Feige was the most important participant of the interviews. His ambition to research and experiment about different building materials out of woad are the basis for the typical uses. He developed wood impregnation, as well as stone and paper

conservation corrosives. Moreover, glazes and paints for wood, stone and plaster were manufactured and distributed by the Thüringer Waid Verarbeitungs GmbH. At the moment these products are still produced by Anke Stiller and distributed online on a website for ecological building materials in small quantities. Certainly, there are good chances to retail these ecological building materials on the market on a bigger scale, due to the higher attention of society to eco-friendly products. Previous research of the DZHD indicates a promising potential of the Thuringian woad coating system for wood, and the coating system has been involved in the new weathering project of the DZHD in Fulda in 2019.

Others functions of woad are for instance in the medical and cosmetical market. For the medical application of woad a lot of research projects and studies have been conducted, a selection of these is shown in Table 1: “literature for the exploration of business ideas of the woad plant”. For producing woad products for the medical market, the main problem is the intensive costs for clinical studies to acquire the authorisation to sell products. On the cosmetical market woad products could be established. There are a few businesses, who are selling cosmetical woad products. The regulatory requirements for a cosmetical product are fewer and therefore less cost intensive than for medical products. The medical field is a suitable example for the difficulties implemented when the conducted research is promising, but the realisation of a medical product on the market is very difficult.

Renate Kaiser-Alexnat conducted a study about the phytosanitary attributes of woad in order to explore its function as a biological herbicide. The investigation based on pot experiments under greenhouse conditions with the introduction of decomposed woad fruits into the soil proved, that the germ inhibiting effect is present. Although, the applied form of application is too expensive for field conditions, the allelopathic effect could be of interest for certain applications such as biological plant protection.

The development in this field is influenced to a considerable extent by the research progress and the political promotion for natural plant protection, because there is a enormous demand in the ecological agriculture for an alternative to the conventional pesticides and herbicides.

As the supplement for animal nutrition or even food for humans the woad could be a beneficial application for animal health by using of the high glucobrassicin content of

woad. In Sicily, recently a research project investigated the leaves and flowers of the woad plant, which have been used as food for humans in Sicily. Before Isatis tinctoria could play a part for the human health as a “super food”, more research and further cost intensive clinical studies need to be carried out.

The extraction of blue from the dying plant woad for textiles and for art is the most prominent application and of historical importance for Europe. In France, but also in Germany dying experts, like Rosanna Minelli from Erfurt, keep the extraordinary art of dying with dyers woad alive and produce valuable products, which have also traditional significance. Furthermore, the demand for natural dyestuff is rising again, probably due to the rising environmentally awareness within society.

9 SELF REFLECTION

Woad was never something new for me, due to the fact that the buildings of my home were renovated with the woad plant when I was 3 years old and therefore the plant was always “around me” and present. In 1995 and 1996, the outside facade of my home as well as two other buildings in Thüngen were renovated exclusively with the natural material Thüringer woad as a Bavarian pilot project, with the collaboration of the preservation of historical monuments (Denkmalschutz) in Bavaria.

As a Master student, we are obliged to choose a final project on a topic that is important to us. Considering my agricultural background and my strong attachment to rural areas and agriculture, I decided to write my master's thesis on "woad". Prior to that, I completed a bachelor’s degree in agriculture in Göttingen at the Georg August University and wrote my bachelor thesis as well about “Thüringer Waid”. The bachelor thesis was focused more on the cultivation of the plant and possible applications based on literature reviews. I come from an agricultural farm in Lower Franconia near Würzburg and will run our farm in the future. For me as a young farmer, the question of where the greatest opportunities lye in today's agricultural market is becoming increasingly crucial, precisely, since the consumer demand for ecological and natural products is increasing.

Personally, I believe woad has great potential to be developed into ecological and natural products in various markets. As indispensable condition for the success of any woad product on the market, I see the requirement of working and planning together with responsible persons of politics and science, because without help in these areas, to develop any business further than the idea, would be very difficult. However, for the different market opportunities of woad products, there are certainly promising developments and chances for additional diversification of business in times of agricultural economic uncertainty.

10 APPENDIX

10.1 REFERENCES

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